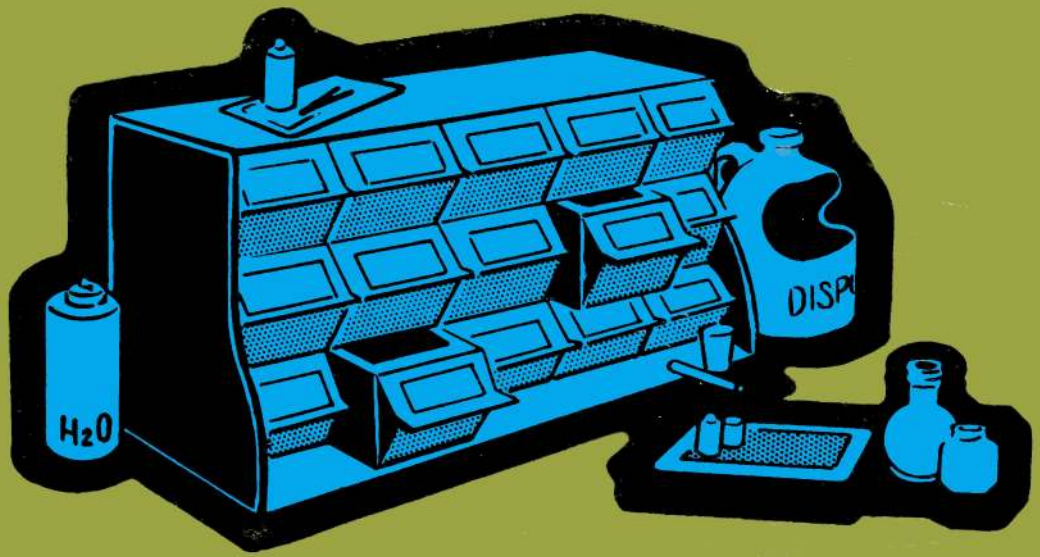
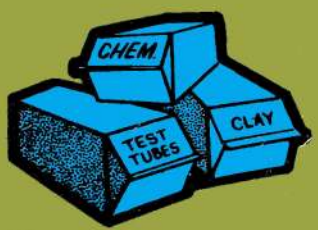


How to Make and Use a Microlab

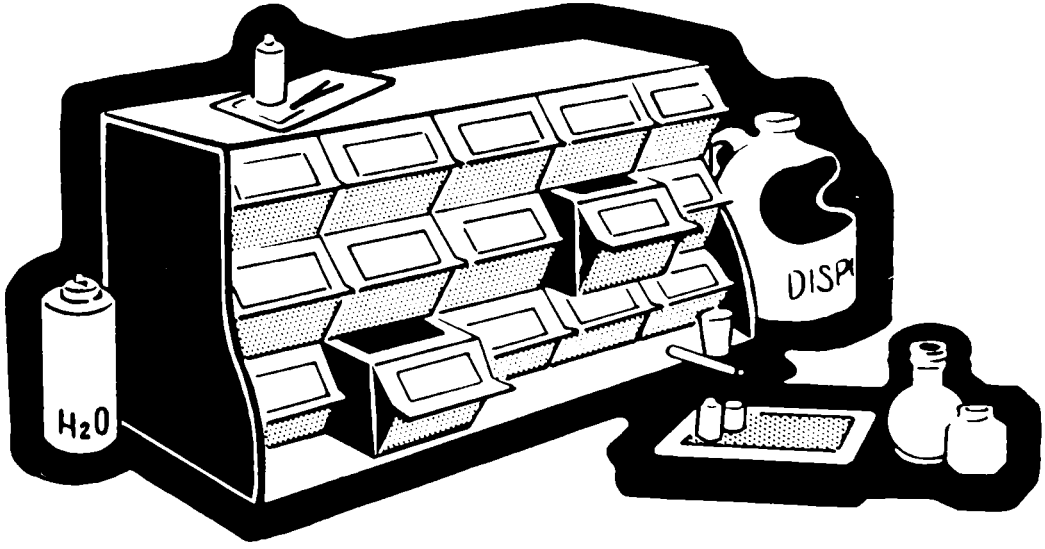
AL G. RENNER



How to Make and Use a Microlab

About the Book

For the young scientist, his laboratory need not be a vast space with ultrasophisticated equipment. The microlab is designed for a small space; it may even be stored in a closet. The equipment for the microlab and the items for a large variety of experiments all can be gathered around the house or from helpful neighbors or storekeepers.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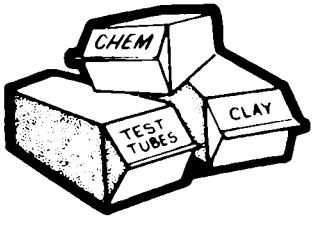
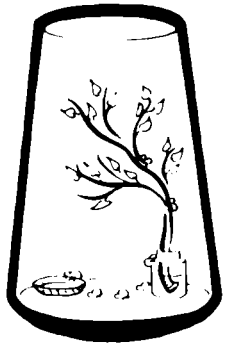
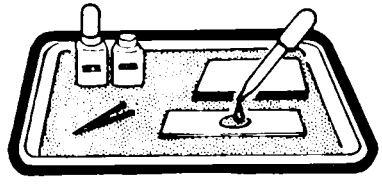
How to Make and Use a Microlab

AL G. RENNER







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Books for the Young Scientist by William Moore

Your Science Fair Project
The reader is given starting points from which to develop his own experiments and projects.

How Fast? How Far? How Much?
The methods scientists use to determine such facts as the age of the earth, the distances to planets, and a thousand and one other details of measurement.

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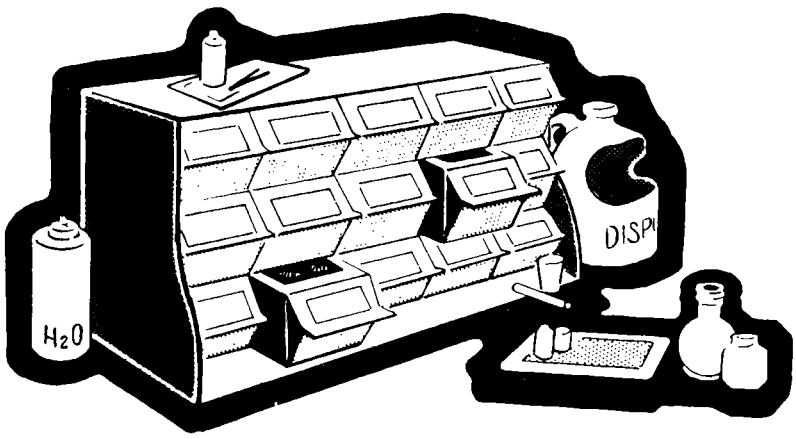
Science Projects: 3
Projects for young scientists in grades 2, 3, and 4.

Science Projects: 4
Projects for young scientists in grades 3, 4, and 5.

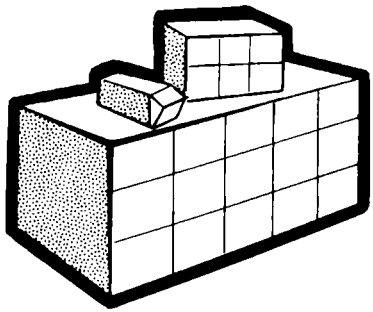
1 How To Build A Microlab



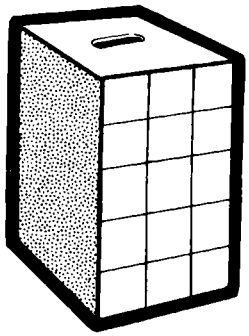
Microlab Organizer

A microlab is an organizer for the equipment of an experimenter. The word "micro" means small, and the abbreviation "lab," of course, refers to the scientist's laboratory. This is the place where he works and does his experimenting. A laboratory, however, is not necessarily a room. It can be a pond, a space capsule, or the outdoors. Your laboratory will be the place where you do your experimenting.

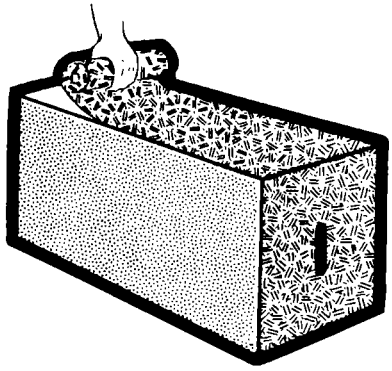
A small lab which you can put on your desk to start your experimenting and which you can put away easily when you are finished working will make you a much more popular member of the family.



Apple box with milk carton equipment drawers



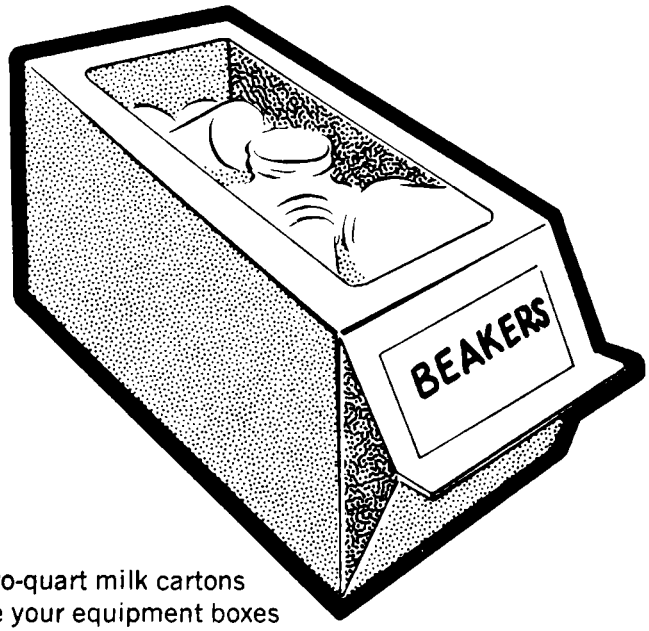
It takes less space in standing position



Cover with colorful contact paper

A good box for a microlab is one which is both large enough to hold your equipment and a size that can fit into your closet or cupboard. Standard cardboard apple boxes are best. Some coffee cartons for one-pound cans have an "egg crate" that holds a dozen milk cartons. However, you must ask the grocer to save these for you because they usually are taken from the box and folded flat to be discarded each day.

Cut hand holes in the ends to make carrying easier. And consider the possibility of using your lab in a vertical position. It will be easier to carry, and it will take up less space in this position. Colorful contact paper can be glued over the outside to brighten up your lab. There is no need to build shelves for your microlab, as you will see when you turn to the next page.

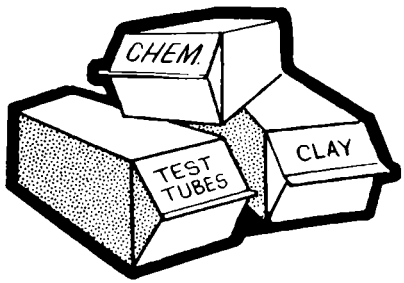


Two-quart milk cartons
are your equipment boxes

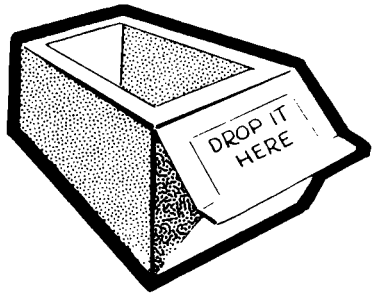
Filing Boxes for Equipment

Take some two-quart milk cartons to the market when you go to pick out your microlab box. Pick a box that will hold them snugly.

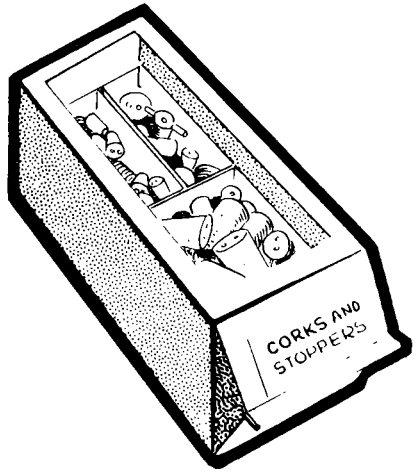
The top of a milk carton can be cut with a razor blade, scissors, or knife. The razor blade does the quickest and the cleanest job if you can use it skillfully and safely. It is extremely important that you leave the half-inch border around the top of the milk carton. This border makes the box stronger so that it will last much longer; it keeps things from sliding out when the box gets tipped; and, most important of all, it enables the boxes to slide over each other, eliminating the need for shelves.



Label with a felt pen



Plan a drop box



Use small milk cartons for divider boxes

Label the filing boxes of your microlab organizer so that you can identify the contents easily. Be sure to get the kind of label paper that will stick to plastic. Use a felt pen for the lettering.

Include a drop box in your planning. This is the box where you drop things when you are in a hurry instead of leaving them out to clutter up the house.

Take advantage of the possibility of putting smaller milk cartons inside the two-quart size for dividing compartments. Never nail or glue dividers inside this kind of box. Always use smaller compartments which can be removed with their contents.

If your storage space is too small for the gabled ends of the two-quart cartons, they can be made square-ended by opening the gable and slitting the four bent edges. Then they can be folded flat and stapled.

The Advantages of Micro Technique

A microlab is successful only when used with micro technique. Micro technique refers to methods of experimenting that use miniature equipment and small amounts of materials whenever possible. Micro techniques are especially advantageous for the savings they produce in space, time, money, and accidents.

Micro techniques save space. Space conservation is being given much more thought in this increasingly crowded world. Big-city dwellers are getting adjusted to apartment living. Schools are being built with less storage space. You will find enthusiastic laboratory assistants available in your family if your experimenting does not get in their way. If you ask your parents, you may find that they studied chemistry with the standard 500-milliliter-size equipment. Most micro techniques are based on 50-milliliter-size beakers and flasks. This means that they are only a tenth as large. And you can store ten times as much equipment in the same space. Your laboratory will not take up enough space to bother anyone if you organize it well.

Micro techniques save time. Time is even more important than space to most Americans. It will not take you as much time to set up an experiment using micro techniques as using standard equipment and techniques; and you will have less to clean up afterward. Schools which teach chemistry with micro techniques usually do more than twice as much experimenting.

Micro techniques save you money. The cost of equipment and especially of chemicals is reduced when micro techniques are used.

Micro techniques save accidents. Micro techniques enable you to do safely many experiments which you could never attempt with the large standard equipment. Small burners are easier to control, little acid does little harm, and small amounts of chemicals can cause little harm, even if mixed improperly.

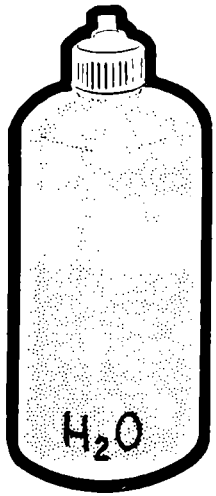
Disposable Items for Science Equipment

Here is a list of disposable items which often have been used to improvise science equipment. Copy the list, and check off the items as you find them. If you make several copies, your friends can help you. It is fun just to take some time to develop your microlab before you start experimenting to solve problems.

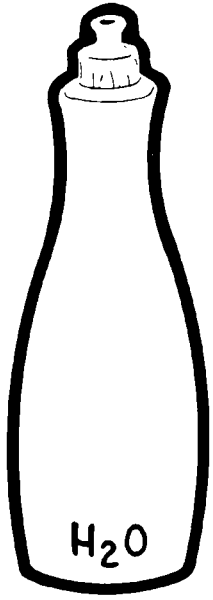
The following pages will show you how to improvise these disposable items into science equipment. Also, some of the micro techniques which will help you get the most use out of each piece of equipment will be shown. You will understand and appreciate good equipment more after you have made and have used your own.

The last section of this book will challenge you with many problems which you can solve using your microlab and the equipment you are about to make.

Toothpicks
Coat hangers
Plastic tubing
Soda straws
Ice-cream sticks
Plastic squeeze bottles
Small bottles and vials
Plastic margarine tubs
Ice-cream and salad cups
Pet food cans
Plastic foam cups
Plastic tumblers
Wooden clothespins
Bottle and jar tops
Plasticine clay
Rubber bands
Baby food bottles
Corks and stoppers
Medicine droppers
Foam plastic meat trays
Single-edge razor blades
Paper clips
Pins, needles, and thread
Light bulbs



Polyethylene
water bottle



Butyrate
water bottle

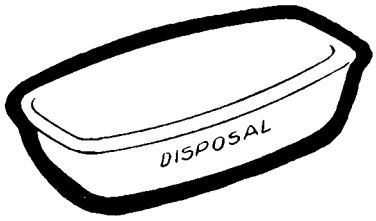
Water "Faucet"

Use a plastic squirt bottle for your water "faucet." Micro equipment does not demand large quantities of water. A squeeze bottle is better for elementary science than a real faucet because it can supply the water anytime at any place. You are not handicapped by the plumbing.

The best squeeze bottles for this purpose are the lock-top polyethylene plastic bottles. Clear butyrate plastic bottles are also excellent. Detergent squeeze bottles do not always have lock tops, but they can serve until other models are available.

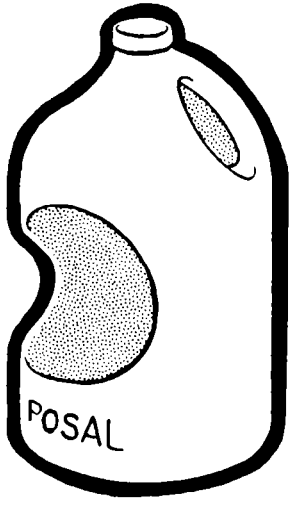
Plastic squeeze bottles are handy dispensers for many liquid chemicals other than water.

Remove the labels from your squeeze bottles by scraping them with a razor blade held at a right angle to the surface. The scraping produces a slightly rough finish which holds felt-pen lettering very well.



Margarine tub

Ice cream cup



Bleach bottle

Sink and Sewer

Expensive plumbing is not as necessary in the modern laboratory as it was before the arrival of disposable plastics. Squeeze bottles are replacing water faucets. And now there is such a great number of plastic containers which can serve at any convenient location that you can have your pick of sizes.

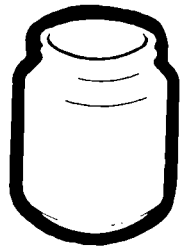
Margarine trays are best when you want a small size. Ice-cream cups and salad trays have served well for many years now. Gallon bleach bottles with a hole cut in the front hold still more waste material. And plastic pails and wastebaskets have done the job well when still larger disposal containers were needed.

Beaker

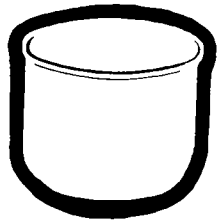
A baby food bottle is by far the best improvised micro beaker. You can boil water in it even on a metal hot plate whereas most bottles will crack.

Aluminum soup cans and tinned pet food cans have been used for many years by students who did not have the standard laboratory glassware for boiling liquids. The aluminum soup cans have round corners which makes cleaning easier.

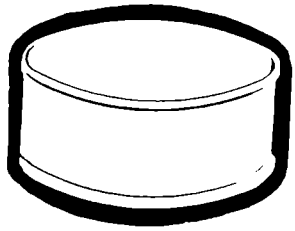
Medical laboratories dispose of 30-milliliter plastic beakers every day. Nurses often save them for science students. The same container without the calibration markings is used by restaurants to serve honey, jam, and syrup each day.



Baby food bottle



Aluminum soup can



Pet food can

Small medical beaker

Light-Bulb Flask

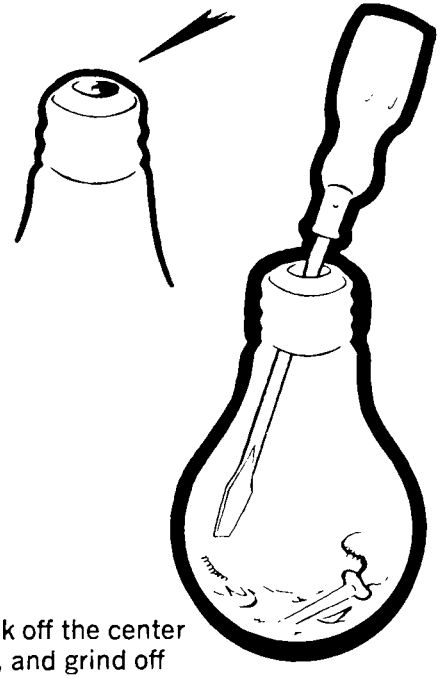
Light bulbs seem to be quite fragile as they drop and break. Perhaps we just notice them more because of the interesting sound which they make. However, light bulbs are quite rugged in another way. They take severe changes in temperature quite easily, and that is one quality which a good flask must have. Have you ever stopped to think how an outdoor light bulb, in freezing winter weather, can be turned on and off thousands of times in its life? Each time the inside temperature can change from freezing to hotter than boiling in a few seconds. This property of light-bulb glass is excellent for flasks. Flasks are bottles which are made especially for heating liquids in the laboratory.

When you pop the sealing wax out of the base of the light bulb, try not to dent the aluminum guard which screws into the socket because you will want corks and stoppers to fit into it snugly. The glass center post of the light bulb is broken by pressing sideways with a screwdriver. Break away the inside glass which held the post. Invert the bulb and shake out the broken pieces. Smooth the inside edge of the glass by scraping with the side of the screwdriver or with a triangular file. Because you will never put your finger through the small opening in this flask, there is little danger of being cut even if you don't grind off all the sharp edges. This grinding really is done so that the liquids can be poured out of the flask more easily.

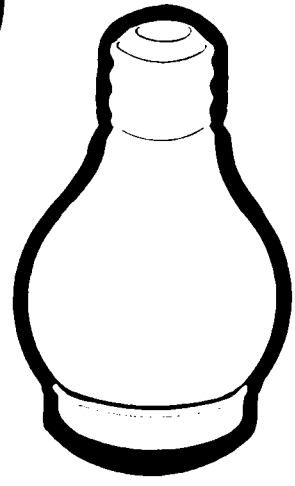
Your round-bottom light-bulb flask will stand quite steadily if you put a liquid inside and place it on a bottle cap. Take the cardboard liner out of the bottle cap before you put the flask on a hot plate to be heated.

Break off the terminal.

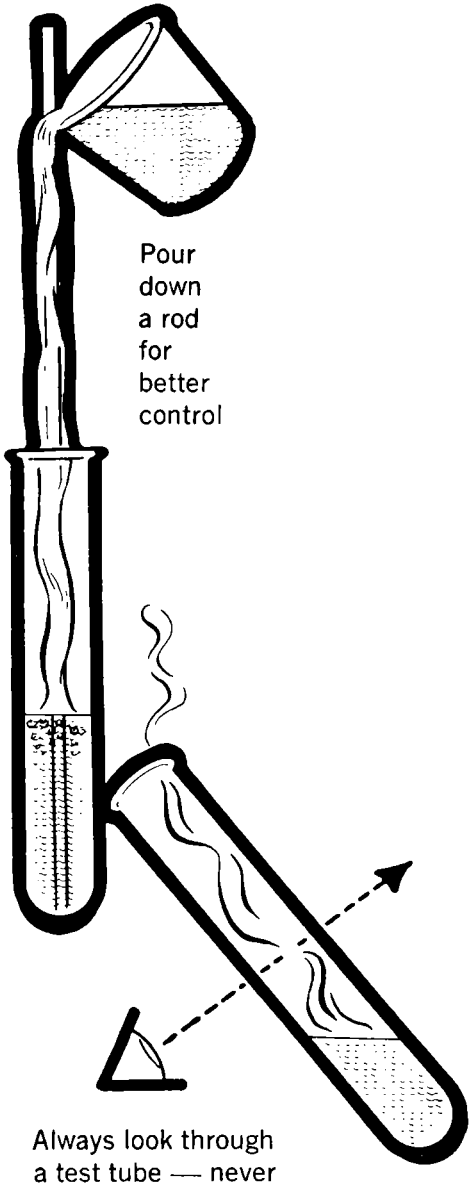
Pop out the sealing wax.



Break off the center post, and grind off the rough edges.



Stand the flask on a bottle top.



Always look through a test tube — never into it

Test Tube

Good test tubes are hard to improvise. There is nothing like a good Pyrex 10-milliliter test tube for heating and testing small amounts of liquids. And small amounts of liquids are what micro technique deals with most of the time.

Pour down a glass stirring rod or pencil for better control when filling a test tube or any other small-mouth container.

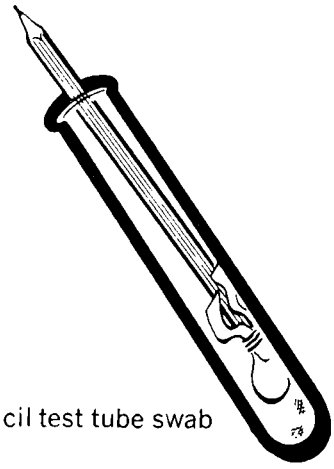
Always look through test tubes; never look into them. This is especially good advice when you are boiling a liquid. You must always point the mouth of a test tube away from you and your friends when it is being heated.

The test-tube swab for cleaning is made by wrapping a micro rag around the end of a pencil and securing it with a small rubber band.

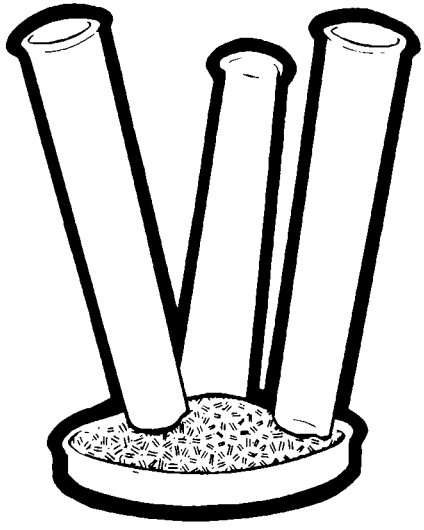
The most convenient test-tube stand is a large bottle cap filled with clay. Several test tubes can be displayed in one bottle cap. Be sure to dry the glass tube well before forcing it into the clay.

Cover test tubes with a small tab of waxed paper or aluminum foil so that the chemical does not touch your finger when you shake it.

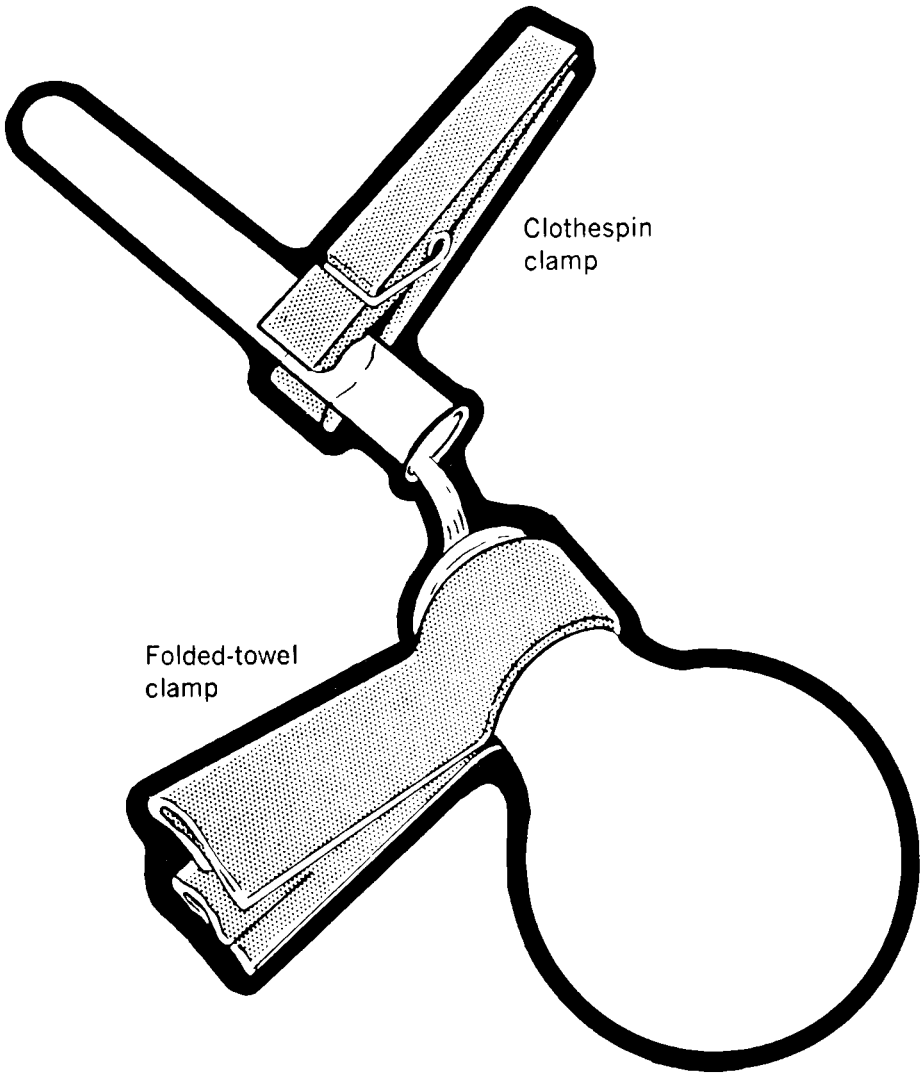
Glass and plastic vials can be improvised into test tubes. However, they will never replace good Pyrex test tubes for heating liquids.



Pencil test tube swab



Clay-in-a-bottle-cap test tube stand



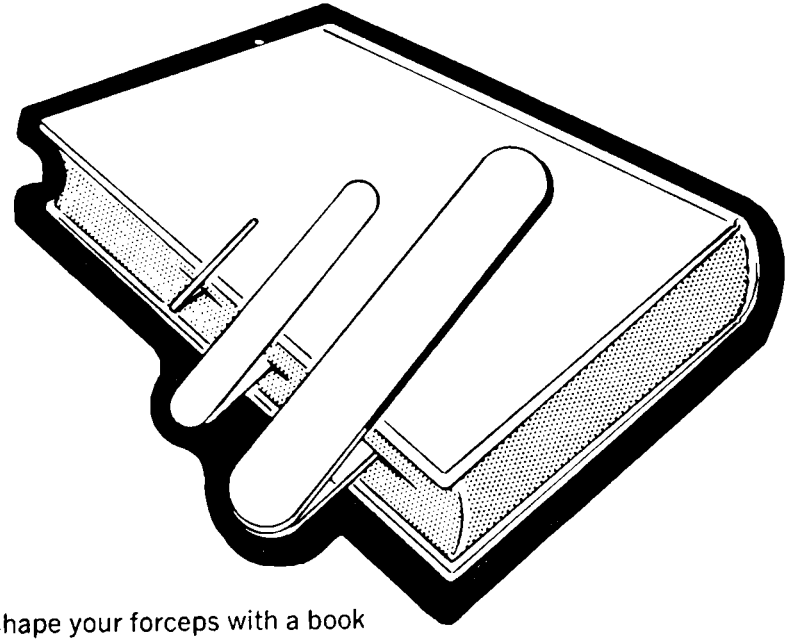
A clothespin is a good test-tube clamp when you work with hot liquids. A paper towel folded one inch wide is an even better all-purpose clamp. With it you can hold hot flasks and even large beakers of hot water.

Forceps

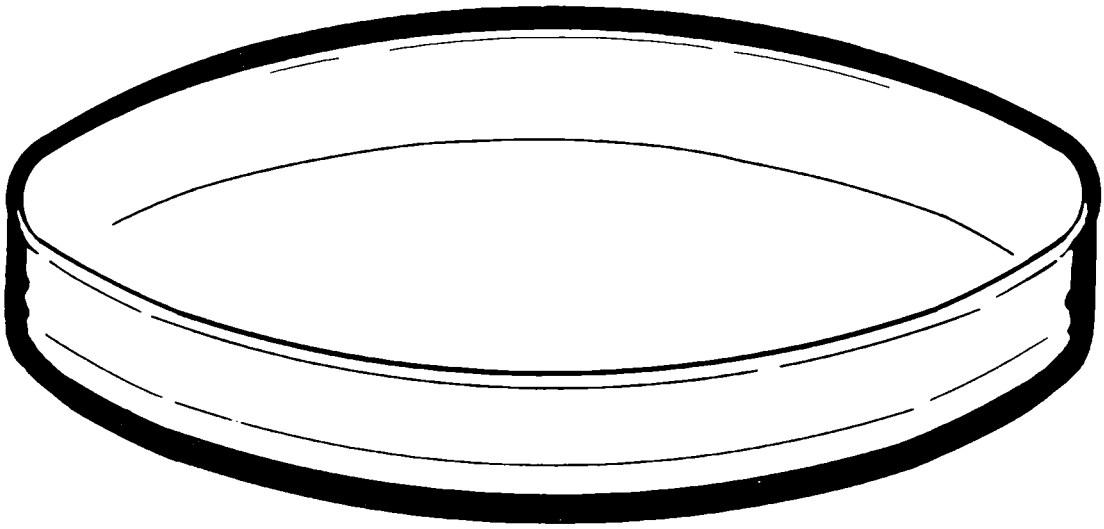
Forceps are made as needed by slipping toothpicks, ice-cream sticks, or tongue depressors into a closed book. Put a generous drop of glue on the exposed end of the stick. And lean the second stick against the cover. The angle of the forceps is enlarged by placing the first stick more deeply into the book.

If you wish to use your forceps to pick up hot objects or even to put them in a burner flame, just soak the blades in a beaker of water before use. When they are charred or dirty, throw them away because they are easy to replace.

An extremely delicate forceps can be made by cutting a ¾-inch strip from a 4-by-6-inch note card. Cut points on the ends, and fold (but do not crease) the two ends together. Try picking up a small insect. You will see that it is impossible to press too hard, thus to injure small, delicate objects.



Shape your forceps with a book



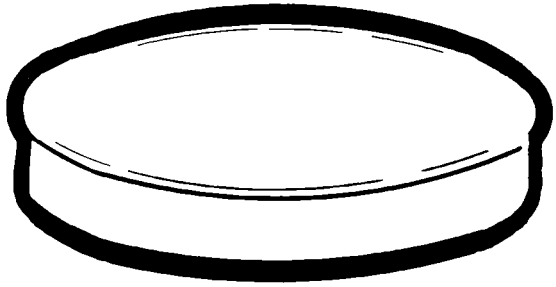
Large jar top

Petri Dish

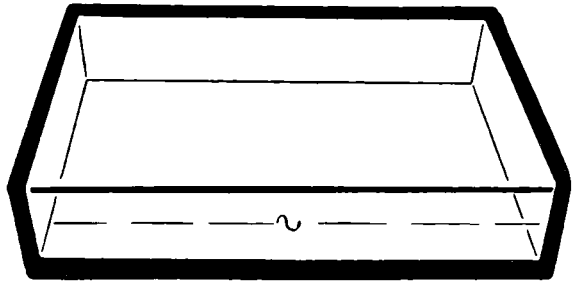
A large jar top makes a fine petri dish. Use a slightly larger top for a cover. Or cover the dish with plastic wrap. Be sure to take out the cardboard liner if you want to heat the dish.

Many small items are sold in small petri-type dishes with covers. Watch for these. And don't forget that modern petri dishes can be square. Many small plastic boxes with covers have all the qualities of a good petri dish.

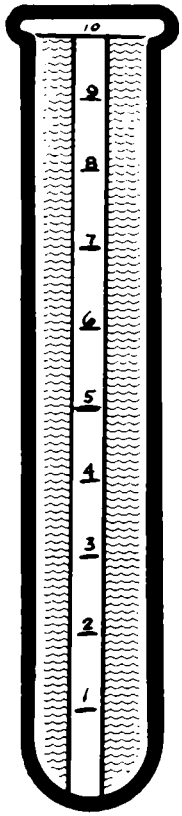
Use petri dishes for growing bacteria and molds. Use them as cages to observe insects. Use them to hold iron filings in your magnetism experiments.



Plastic tape container



Square plastic box



Use test tube or vial
for graduated cylinder

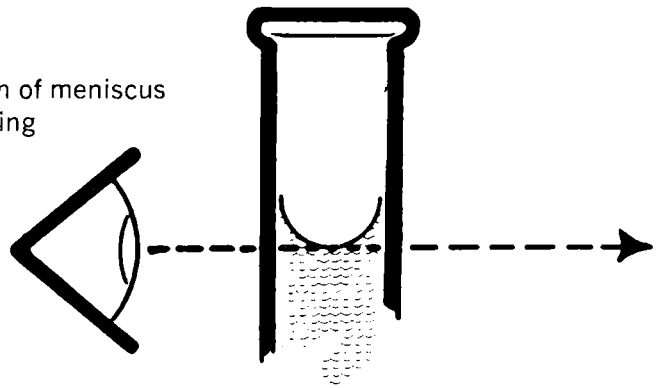
Graduated Cylinder

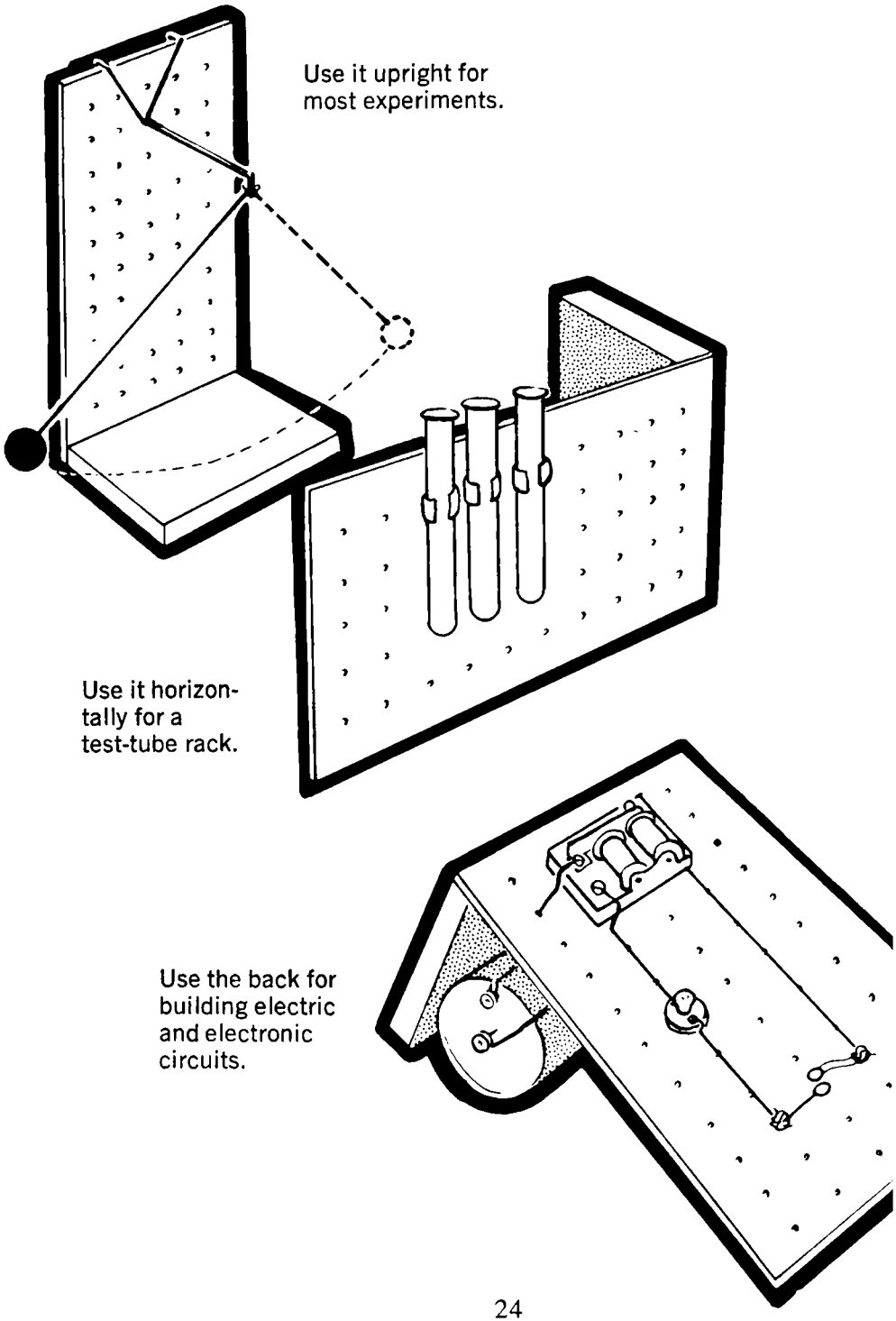
A graduate is a device for measuring volume. Calibrate one of your 10-ml test tubes. Then set it in a base made by putting clay into a bottle cap.

"To calibrate" means to mark an instrument into accurate divisions for measuring. The standard micro test tubes are manufactured so as to measure 10 milliliters quite accurately when filled to the top. Stick a thin strip of masking tape to the side, and mark it into ten equal divisions.

Sight through the bottom of the meniscus to read your graduate accurately. "Meniscus" is the name given to the curved surface of water in small tubes. The bottom of the test tube is made with this same curve so that evenly spaced calibrations will be accurate.

Sight through bottom of meniscus
for accurate measuring




Use it upright for most experiments.
Use it horizontally for a test-tube rack.
Use the back for building electric and electronic circuits.

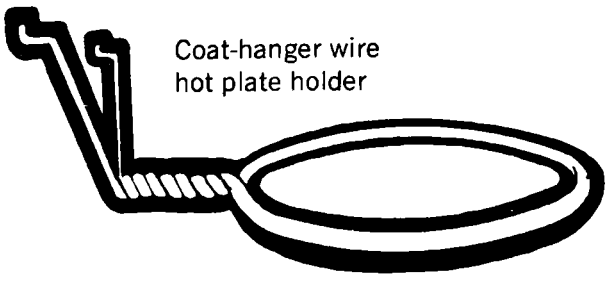
Experiment Stand

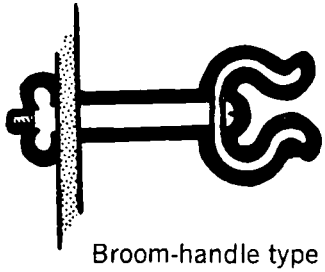
The punchboard experiment stand is very inexpensive and is extremely adjustable. Note the many positions in which it can be used. This stand is easy to make, and it can be cut to any size. A good size to start with is an 8½-by-11-inch stand on a 4-by-8-inch base.

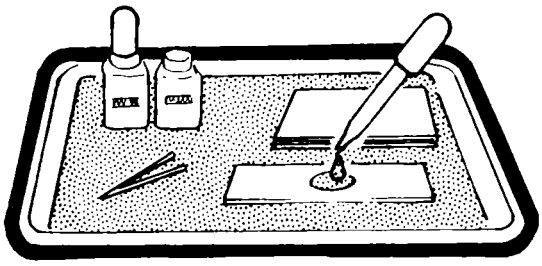
Notice below how the coat-hanger wire is fastened with the double right-angle bend. You can make your holders of any shape or size to meet your needs. Broom-holder-type clamps sometimes are used for test tubes and for flasks. It takes time, however, to bolt these to the backboard. This type of clamp can be fashioned from tin-can metal if you cannot find the right size at a hardware store.

The hot-plate ring is hardest to bend. You will need your pliers to twist the wire tightly. The ring is formed around a bottle or tin can. A larger tin-can lid is used for a hot plate. These lids are better than screen because they keep the smoke off the glassware.

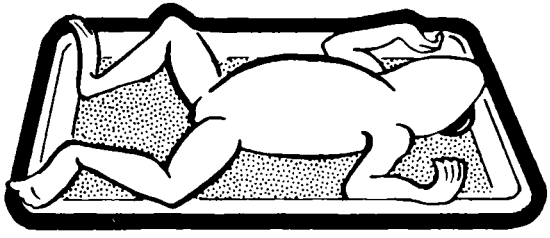
The back side of the experiment stand is ideal for use as a "breadboard" when designing and building electrical and electronic circuits. The circuit is designed on paper, which is then placed on the "breadboard." The components are put in place over the symbols of the drawing. The circuit wires are held in place by lugs, which are made by soldering spring clips to the heads of brass paper fasteners.



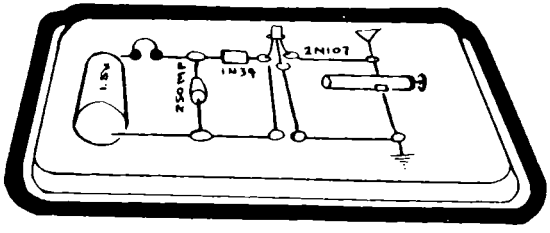




Chemistry tray



Dissecting tray



Electronics tray

Laboratory Tray

Foam-plastic meat trays have many uses in the laboratory. Chemistry experiments should be done in a foam tray on a paper towel ready to catch splashes and spills. When the paper towel is too long for the tray, cut the extra edge off to be used as a small wiper towel. It is so easy to keep your desk clean when you use micro technique.

Foam trays are excellent for dissection. It is easy to stick pins into the foam. A new razor blade is your sharpest cutting instrument. It should have a single cutting edge. Stick a darning needle into the eraser of your pencil for a teasing needle.

Electronic circuits are designed and built on the backs of foam trays. The schematic drawing of the circuit can be sketched on paper or on the bottom of the foam tray with a felt pen. The components are placed over the symbols. Spring clips soldered to thumbtacks are used as lugs to hold the circuit wires in place. The older papier-mâché meat trays are still best when the whole circuit is to be soldered.

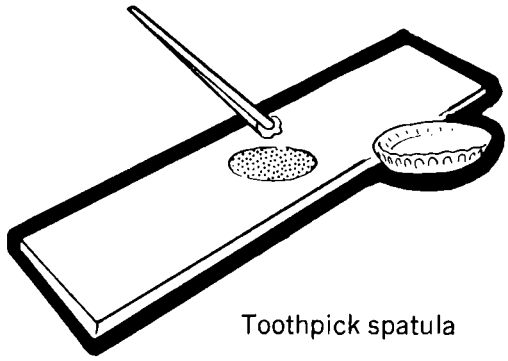
Spatula

A spatula is used like a spoon for measuring small portions of chemicals. Micro technique enables you to use a surprisingly small spatula. In many experiments the powders are ladled with a toothpick spatula into the depression of a microscope slide or into a soft-drink bottle cap.

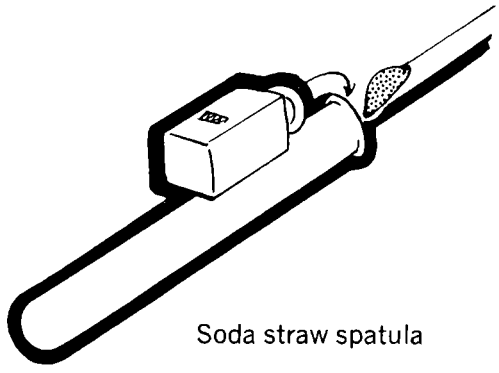
A soda straw which has been cut at an angle is also a good spatula for measuring small portions of chemicals. The opening in the slanted cut measures the same portion each time.

Larger spatulas can be cut from ice-cream sticks and from tongue depressors if needed. Cut the handle so that the measuring end is well defined.

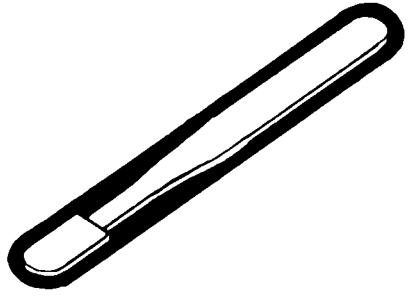
One of the wonderful things about micro technique is that chemicals are seldom spilled and wasted. Transfer your chemicals the shortest possible distance. This distance is almost never more than one inch. Note in the middle drawing how the stock bottle and test tube are held together to transfer the chemical.



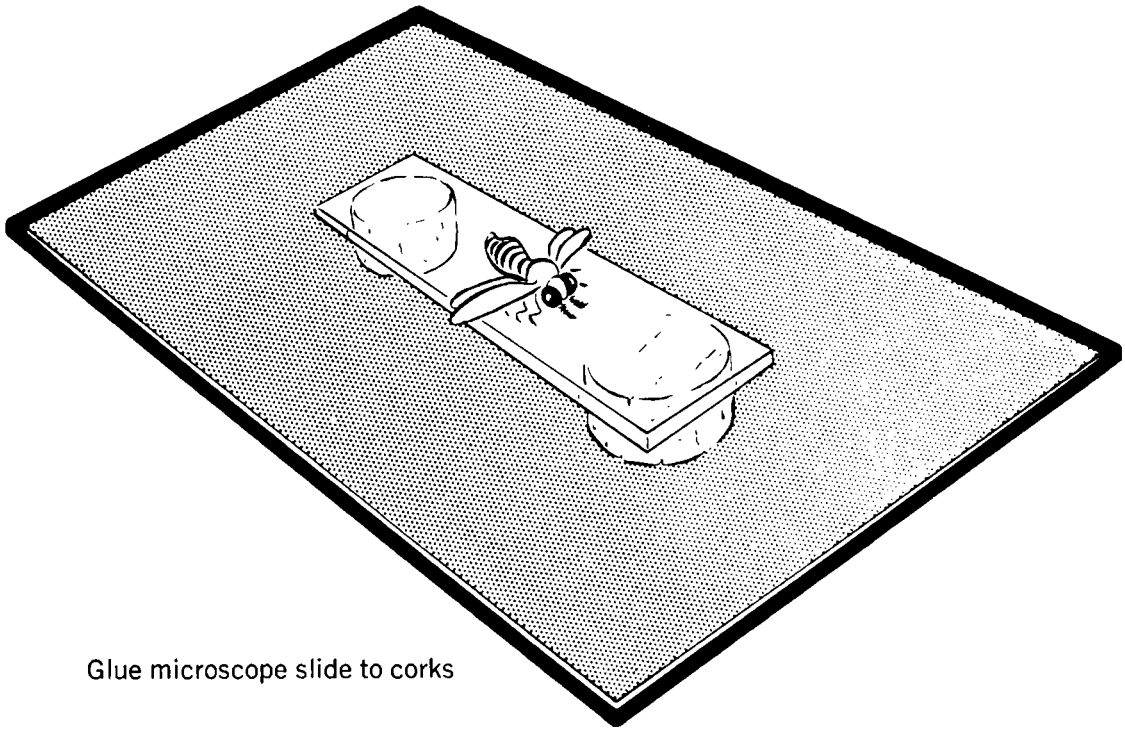
Toothpick spatula



Soda straw spatula



Ice cream stick spatula



Glue microscope slide to corks

Micro Dissecting Table

Your micro dissecting table can be made by gluing two flat corks to a 4-by-6-inch note card with rubber cement. Then glue the microscope-slide table to the tops of the corks. The insect, or any other small specimen, to be dissected is fastened to the micro table with a small drop of rubber cement. Underlight the specimen with a desk lamp or a flashlight.

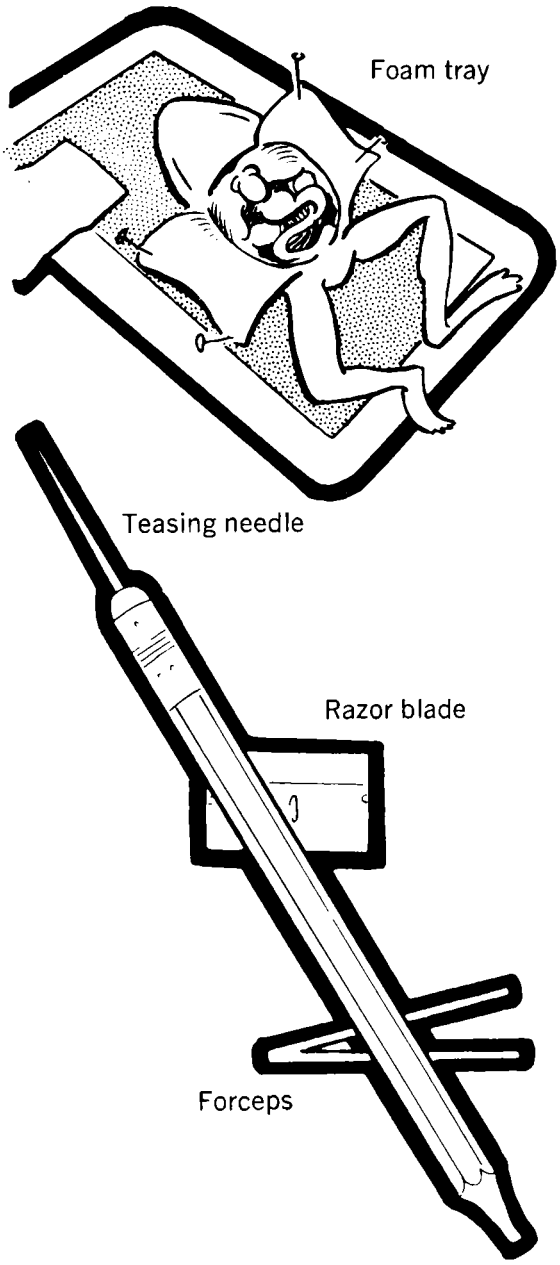
Dissecting Instruments

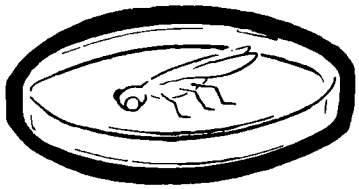
Specimen dissection is much cleaner now that foam plastic meat trays have been invented. A paper towel is placed on the tray, and the specimen is pinned into place. A double-thick tray can be used for pinning large specimens.

Small paper wiping towels should be near. Often these can be cut ends from the towels which have been trimmed to fit the foam trays.

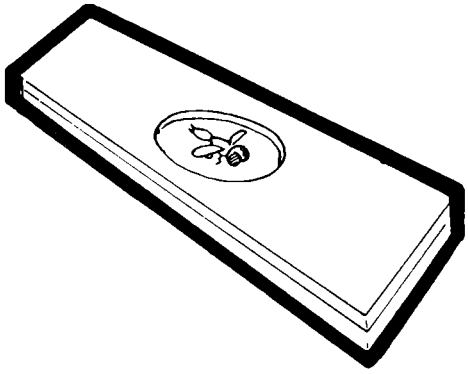
The teasing needle is made by forcing any needle into the eraser of a pencil with pliers. Darning needles are best because a teasing needle should not be sharp.

Practice scalpels are notoriously dull because they usually are not made of the best steel. A single-edge razor blade is by far a better cutting instrument.

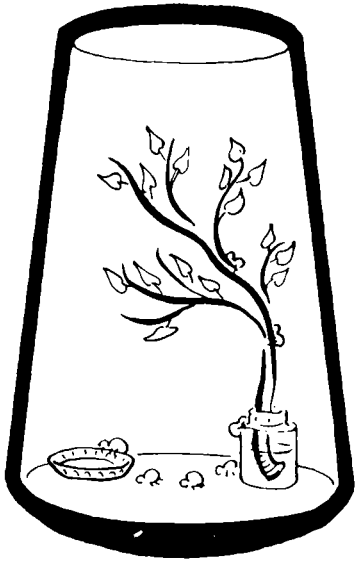




Petri-dish cage



Microscope slide cage



Plastic tumbler cage

Micro Cages

Micro cages, terrariums, and aquariums enable you to study many more living things in a limited space. And they help you make changes more often in caring for your animals.

Petri dishes are good for watching insects which live on plant leaves. Your magnifying lens can be used with the top in place.

Small insects such as aphids, ants, and fruit flies are observed easily under a microscope when caged between two slides with the depressions facing each other. A drop of water near the end can help air pressure hold them together.

In the inverted tumbler terrarium the bottle-top drinking cup and the watering bottle for the plant are rubber-cemented to the large jar lid which holds the sand or soil. Fill the drinking cup with a medicine dropper.

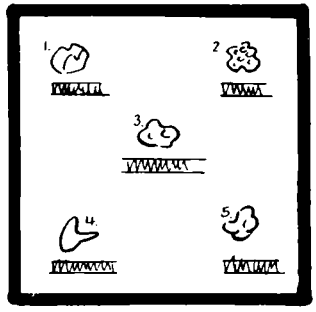
Micro Geology

Micro techniques enhance geological studies, too. Specimens look brilliant under the hand lens or under the microscope because they have not been handled. And think of how much more you can collect when your specimens do not take up much space and do not weigh much. Now you need to save only the best parts of your big rocks and minerals.

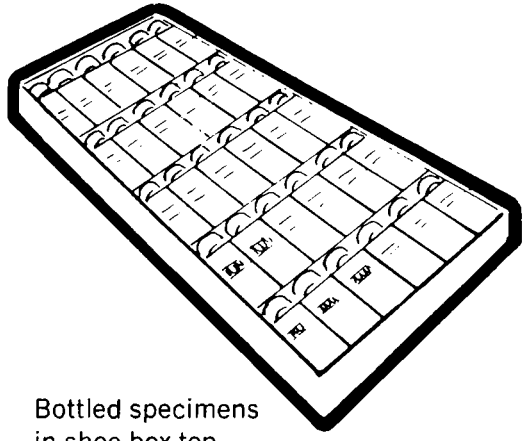
Once your friends know that you have started a micro collection, they will bring you sand, soils, and minerals from their travels. You may even begin receiving them in the mail. This seldom happens when you are making a standard-size collection.

Your spectacular specimens will be put on cards to be viewed with a magnifying glass or microscope. Your stock bottles and extras can be stored flat in shoe-box-top trays. If you use test tubes or vials, they can also be stored this way.

Specimens in micro bottles



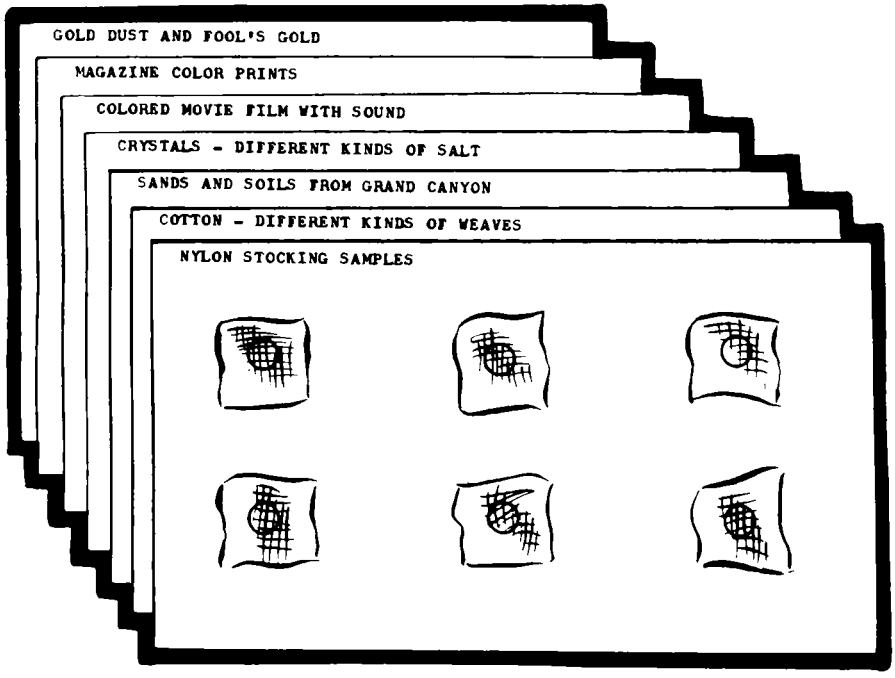
Specimens on 2" x 2" cards



Bottled specimens
in shoe box top

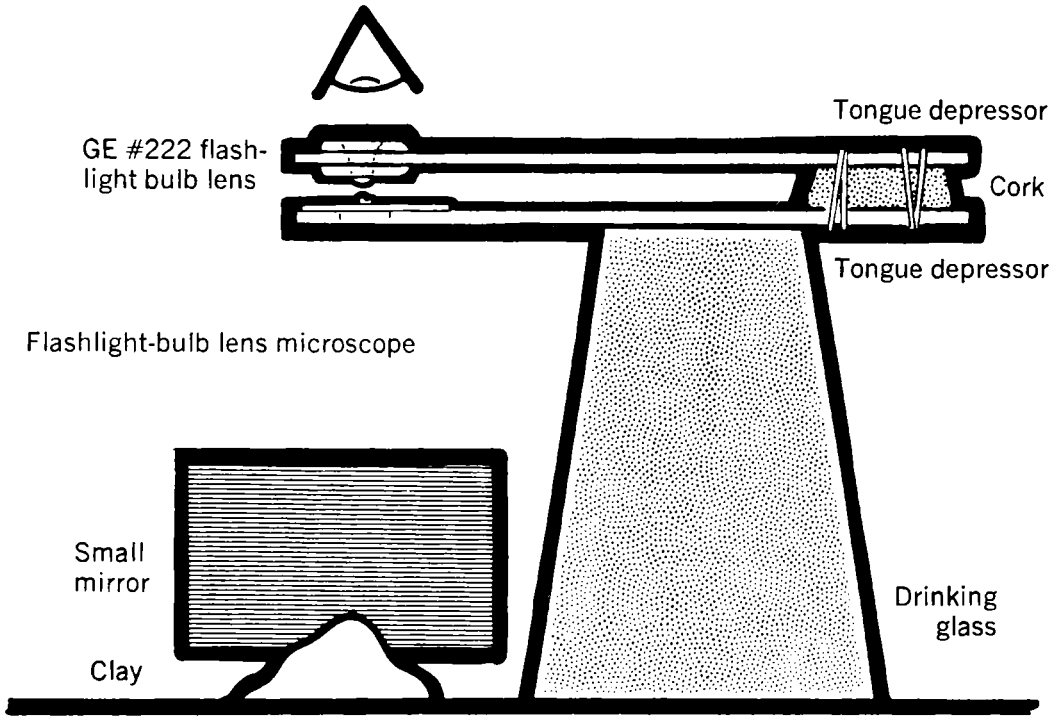
Micro Collections

Micro collections stay in better condition because the specimens are not handled individually, as often happens with larger collections. They are set up to be viewed with a magnifying lens or with a microscope. The popular sizes are 3-by-5-inch note cards and 2-by-2-inch cards. Decide on the placement of your specimens, and type or letter your labels first. Then fasten the specimens with quick-drying glue. Transparent specimens often can be glued over holes punched in the card for better lighting. The 2-by-2-inch collections can be stored in 35-mm photo storage trays for safekeeping.

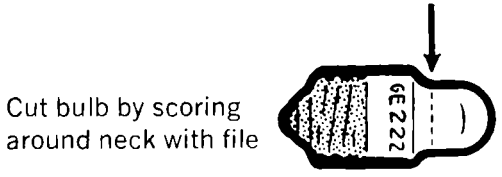

GOLD DUST AND FOOL'S GOLD
MAGAZINE COLOR PRINTS
COLORED MOVIE FILM WITH SOUND
CRYSTALS - DIFFERENT KINDS OF SALT
SANDS AND SOILS FROM GRAND CANYON
COTTON - DIFFERENT KINDS OF WEAVES
NYLON STOCKING SAMPLES

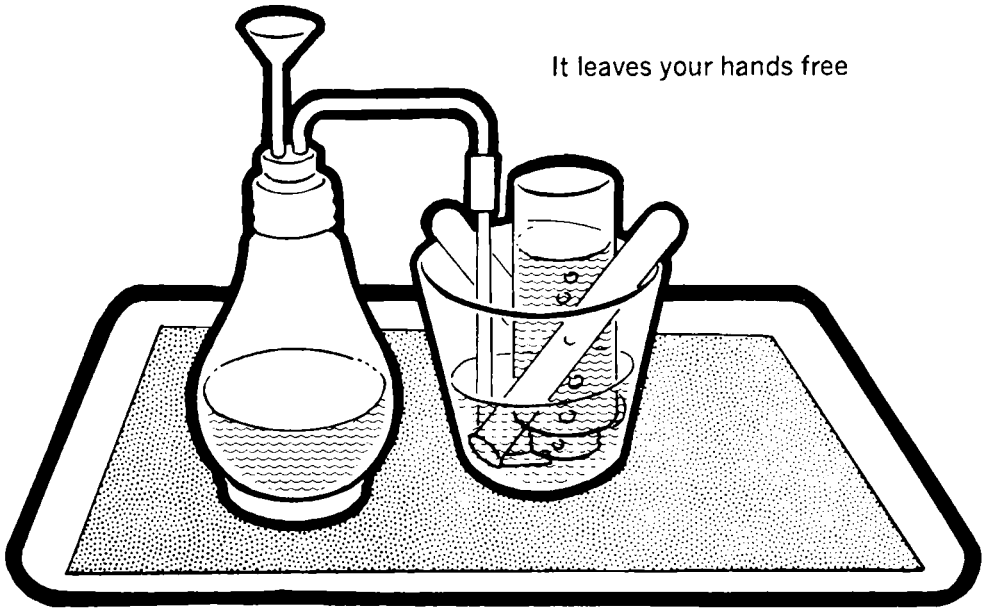
Microscope specimen card file

Microscope



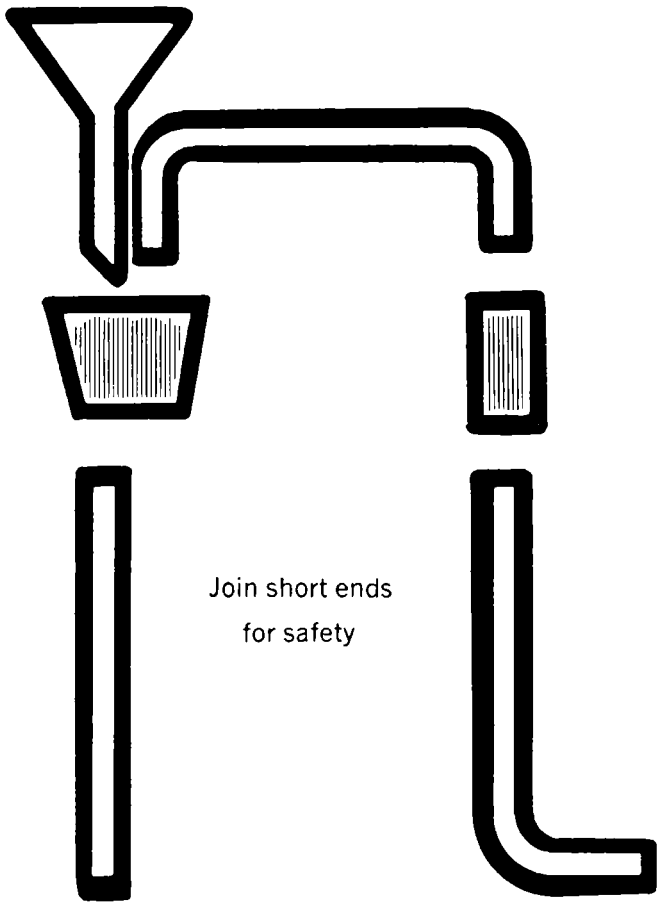
The microscope lens is made by scoring around the neck of a General Electric #222 flashlight bulb with the sharp corner of any file. Lay the bulb flat on the table to do this. Drill holes through both tongue depressors, or cut out holes with a paper punch. The lens can be glued into the hole, or it can be inserted into a ¼-inch rubber grommet. The tongue depressors can be held to the cork with a rubber band, or they can be glued together. Any flexible material can be used to hold the lens. Any small mirror can be set into clay to reflect light upward through the microscope.





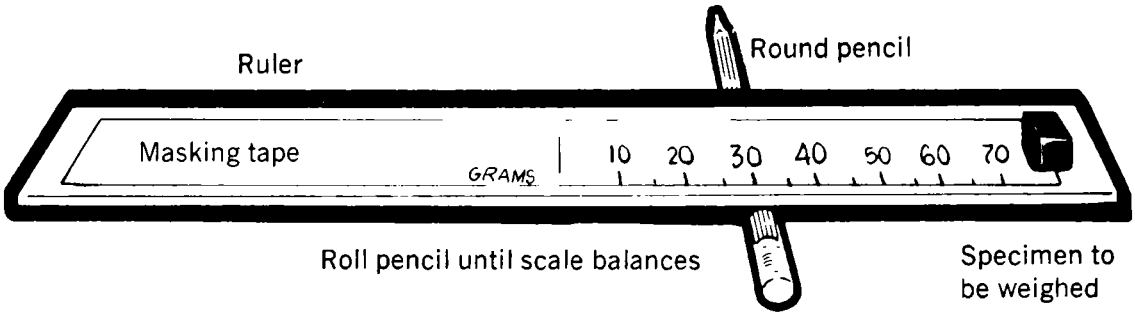
Gas Generator

The technique shown here is one of the more significant contributions of micro technique to the study of chemistry. The long floppy rubber tube and pneumatic trough are needed no longer. The experimenter's hands are free now to make adjustments and take notes. Notice how the wide-mouth plastic drinking tumbler or ice-cream cup holds the collecting bottle and test tubes so well that they cannot spill.



Safety with Glass Tubing

A glass tube is never pushed through a rubber stopper when using micro technique. This eliminates one of the most serious accident factors in the study of chemistry. The smaller parts of micro equipment can always be joined together with corks and stoppers. There is no need for the dangerous task of forcing a glass tube through a rubber stopper, causing it to break suddenly and to jab into your hand. If you do need a long glass tube, as for distillation, join several short sections together with stoppers or corks.

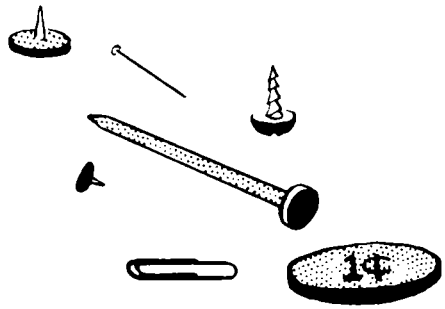


Roll Scale

This is one of the simplest scales known. Just roll the pencil until the beam balances over it. Eventually you will want to use the metric weight system, which is used by every country in the world for scientific purposes, but to begin with, calibrate your scale in any convenient units. Students have used many different small objects for weight units. Some of them are shown below. The only requirement is that the objects be consistent in their weight.

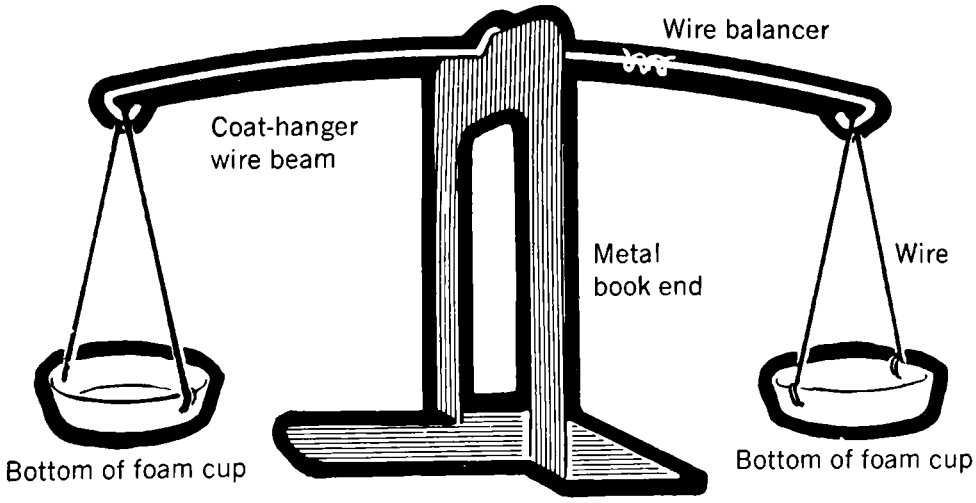
Draw a line or a small circle on one end of your balance beam. Each object to be weighed must be put exactly on the same spot to make this scale accurate. Now roll the scale so that you can mark "0" where it balances in the center. Next add one unit on the weight mark. Mark the spot where it balances with a "1." Anything which balances at this spot will weigh one unit of weight. Record as many units as your scale will hold.

Later you can use a longer beam. And you will also want to make some metric weight units so that you can weigh in grams. See Page 40 for some suggestions for doing this.



Balance Beam Scale

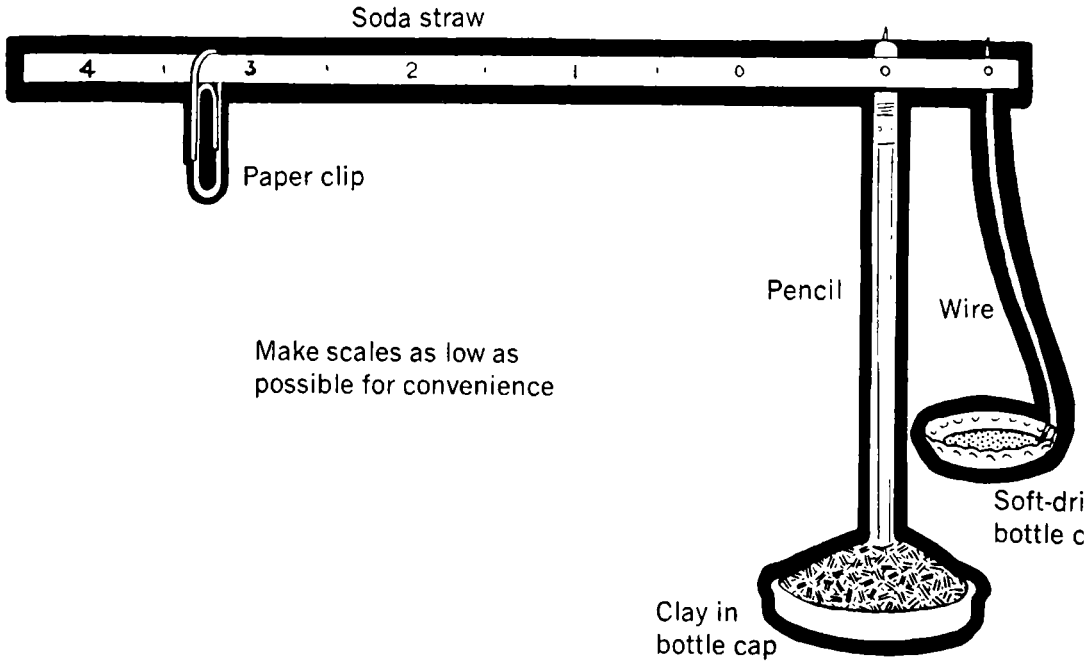
The balance beam of this accurate weighing scale can be made from a coat-hanger wire with your pliers. Cut the wire where it bends on the ends, and turn the ends inward for safety. The stand which supports the scale is a metal bookend. If you do not have a metal bookend, make a pencil stand with a clay base, as shown in the scale on the next page. Take the eraser out of the pencil, and flatten the end of the metal tube with your pliers so that you will have a sharp edge on which to balance the beam of the scale. A rider (balancer) of solder wire or heavy copper wire is twisted around the lightest side of the beam to zero the scale before each weighing. Foam cups make excellent weighing pans for the weights. You may want to cut the top half of the cup away. Copper wire is best for hanging the pans from the beams. You will need a set of weights to use this scale.

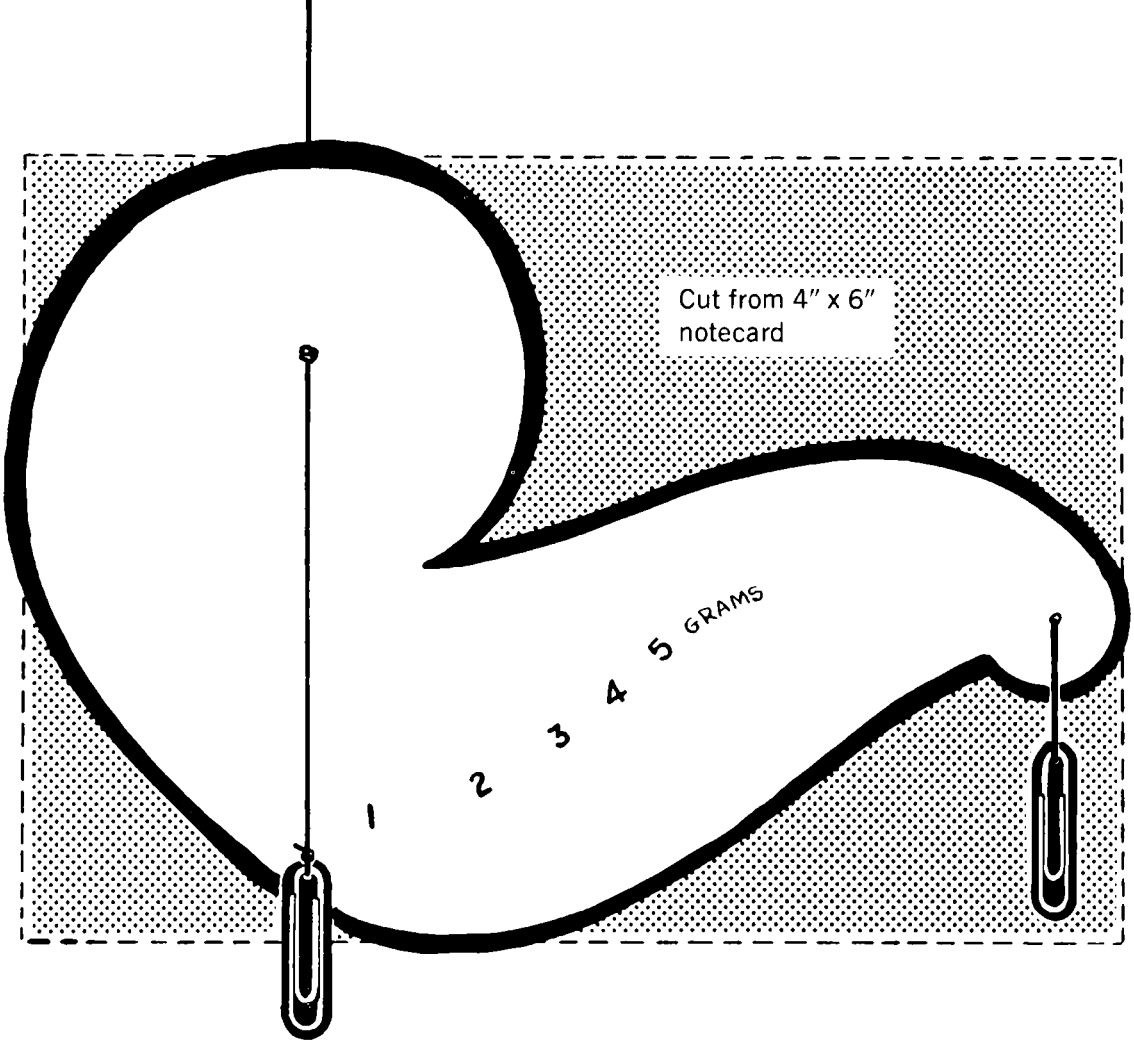


Bend beam ends inward for safety

Unequal-Arm Balance Scale

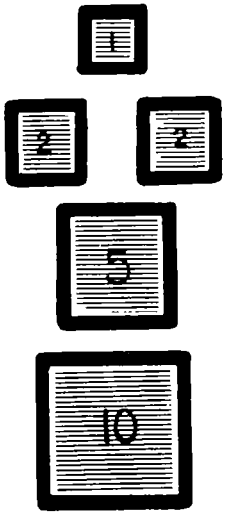
Soda-straw scales such as the one below have been used for many years by young experimenters to weigh small objects. It is good experience to build your own scales and to learn how to adjust them. Mark "0" where your paper clip indicates that the long beam balances the short beam with the empty weighing pan. Add your weights one at a time, and mark where each one is balanced. A ring can be used in place of the paper clip for heavier objects. An electronic alligator clamp is also good because it will not slip. You can calibrate one side of the soda straw for lightweight objects and the other side for heavyweight objects. You even may want to use a chopstick or a coat-hanger beam to make a still stronger scale. Be sure that you learn to use the metric system for weighing and measuring in general as you gain experience. It is the choice of scientists in every country of the world.



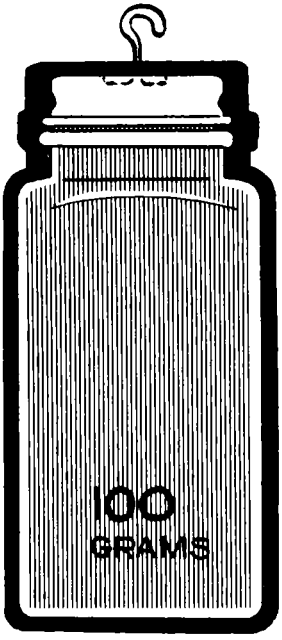


Note Card Scale

This note card scale is adapted from a postage scale made by early American settlers. Instead of weighing envelopes in the paper clip, you could replace the clip with the very bottom of a foam cup supported by a copper wire. Use it for weighing small objects in your science experimenting.



Metric weight set

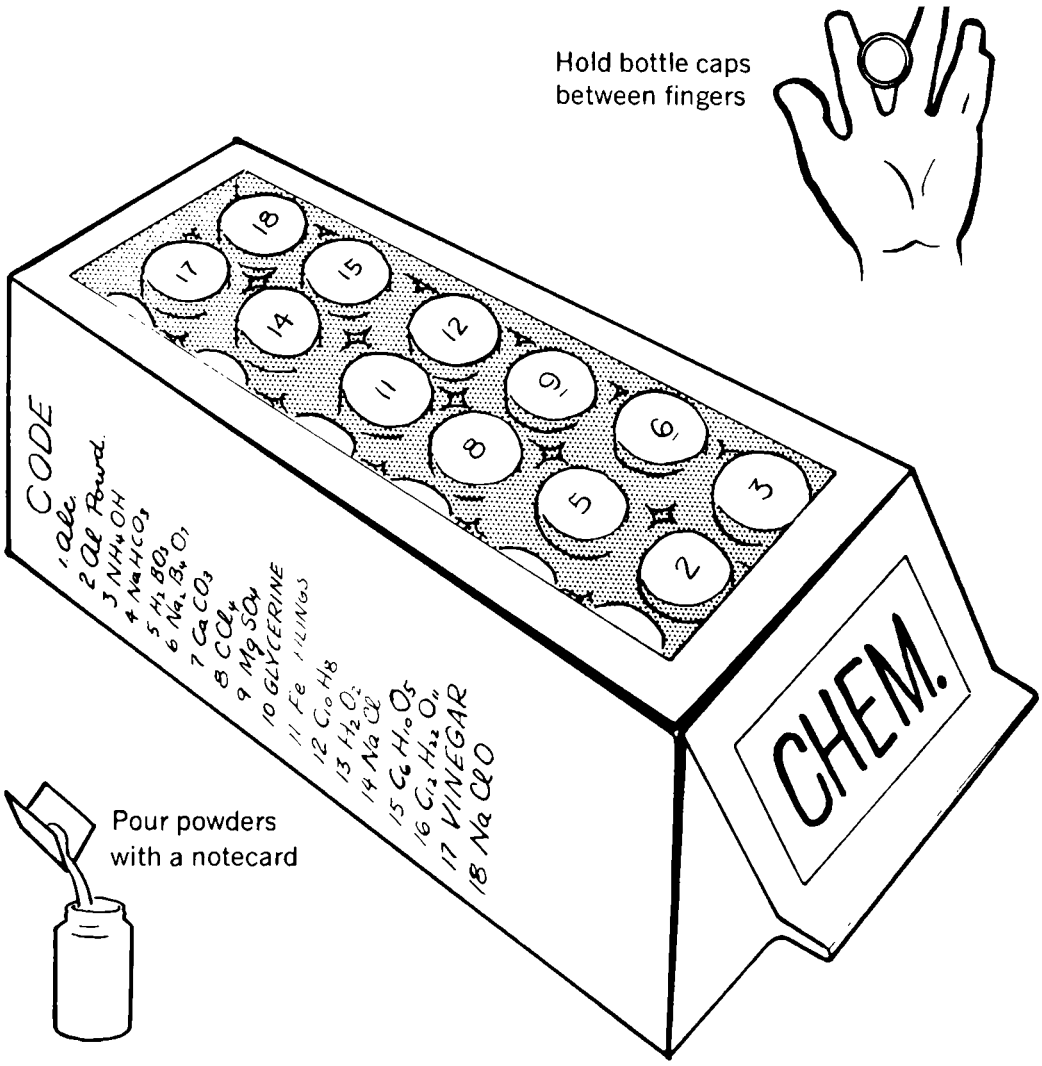


Sand in plastic bottle

Metric Weights

Borrow a set of metric weights, and make your own matching set. Perhaps a science teacher or your local pharmacist can help you. A set consists of a single 1-gram weight, two 2-gram weights, a 5-gram weight, and a 10-gram weight. You will need some aluminum foil and scissors. Start with a large piece of foil, and keep cutting it down until it balances the weight which you are trying to match. Fold and pound each aluminum weight flat with a hammer. There is no need to mark the weights because you will recognize them by size.

Heavier weights can be made most easily by filling plastic bottles with sand. Drill a small hole through the cap, and make a hook with a loop of heavy copper wire. The two ends of the loop are bent inside the cap of the bottle. Solder them to the cap if possible. These weights are unbreakable, and they will not dent your desk.

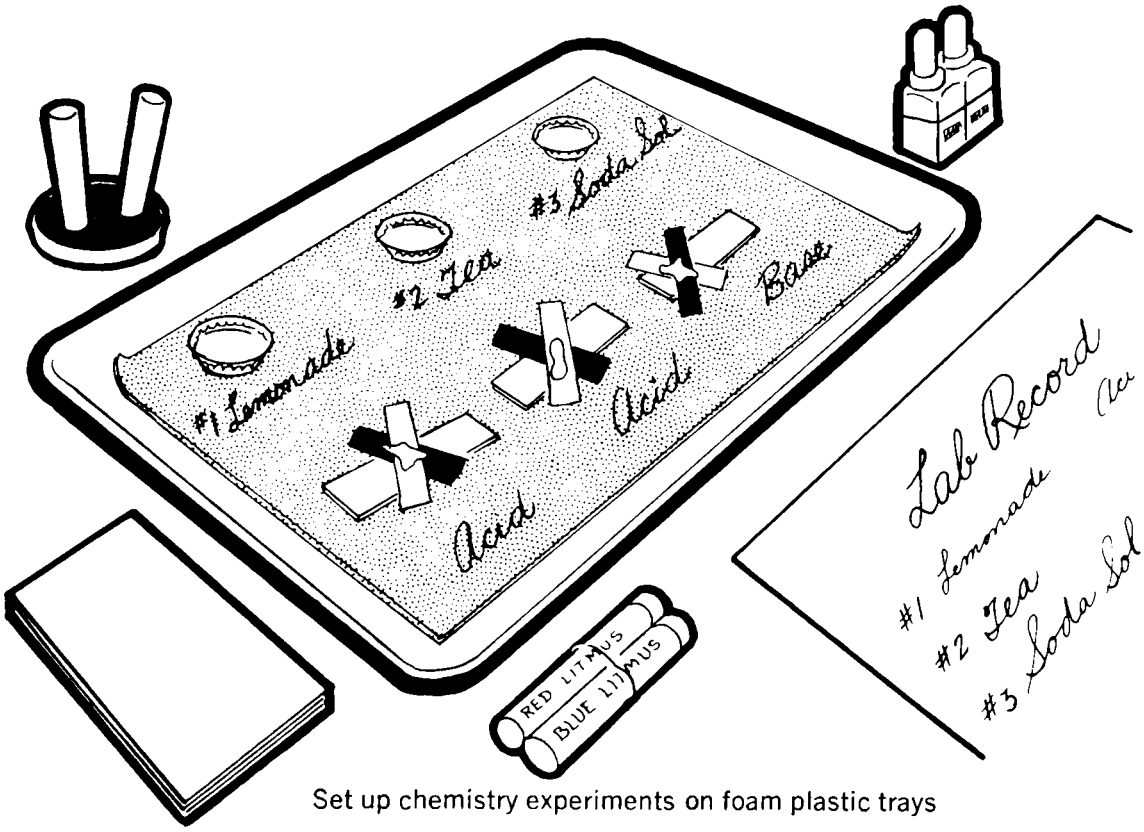


Chemical Bottles

There are about twenty-five chemicals which you usually can find around home to start your chemistry set. These are listed on the next page. You can find in library books many elementary chemistry experiments which make use of these. Type the key to your numbering code and glue it to the side of the storage box. Always be sure that you replace the tops of your bottles tightly so that the chemicals do not attract moisture and harden in the bottles.

Items Which You Can Find at Home

Common Name	Formula or Symbol	Chemical or Common Name
Alcohol, grain	CH_3CH_2OH	Ethanol
Aluminum	Al	Aluminum foil
Ammonia	NH_4OH	Ammonium hydroxide
Baking soda	$NaHCO_3$	Sodium bicarbonate
Borax	$Na_2B_4O_7$	Sodium borate
Boric acid	H_3BO_3	Boric acid
Bleach	NaClO	Sodium hypochlorite
Chalk and egg-shells	$CaCO_3$	Calcium carbonate
Cleaning fluid	CCl_4 and C_6H_6	Carbon tetrachloride and benzine
Epsom salts	$MgSO_4$	Magnesium sulfate
Glycerine	$CH_2OHCHOHCH_2OH$	Glycerol
Iron filings	Fe	Ferrum
Mothballs	$C_{10}H_8$	Naphthalene
Peroxide	H_2O_2	Hydrogen peroxide
Plaster of paris	$CaSO_4$	Calcium sulfate
Salt, table	NaCl	Sodium chloride
Starch	$C_6H_{10}O_5$	Starch
Sugar, table	$C_{12}H_{22}O_{11}$	Sucrose
Vinegar	CH_3COOH	Acetic acid

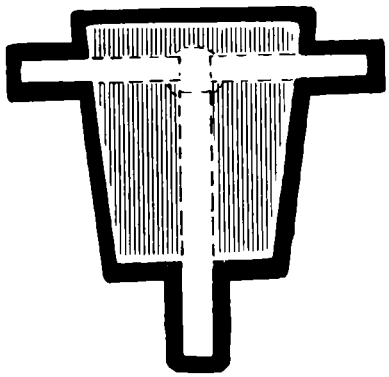


Set up chemistry experiments on foam plastic trays

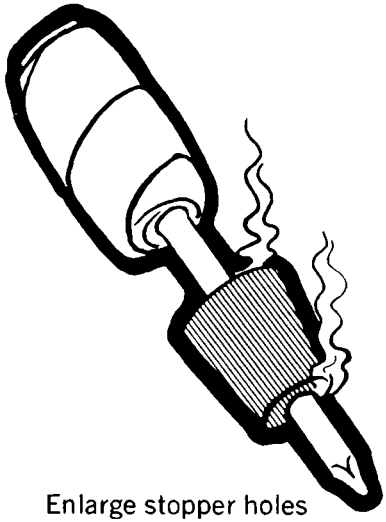
How to Set Up Chemistry Experiments

Foam plastic trays have elevated the household status of the elementary chemist. It is easy now to keep things clean. Put a paper towel in the foam tray for your experimenting. Clean up after each experiment, and replace the towel for the next. Micro technique suggests that most experiments be done on a glass microscope slide or in a soft-drink bottle cap. Toothpicks or soda straws cut at a slant are used to ladle the small portions of chemicals. Liquid chemicals are stored in dropper bottles for easy use. The best test-tube rack is clay in a bottle cap. Ask your local librarian for elementary chemistry books.

Corks and Stoppers



Cork "T" connector

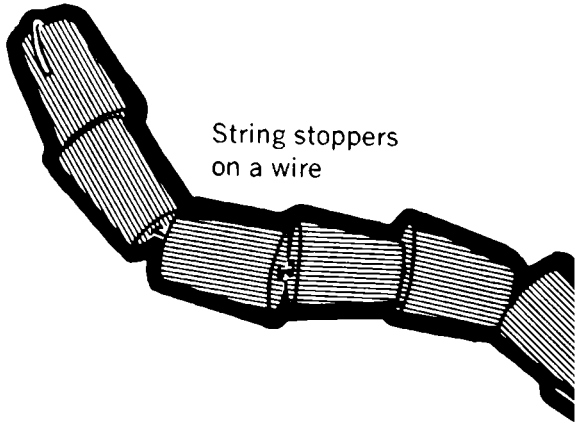


Enlarge stopper holes with a red-hot nail

You will need a variety of corks and stoppers. Your biggest problem will be to make the holes fit the rubber, plastic, and glass tubing. A hole can be made larger by inserting a red-hot nail. Insulate the nail with tape, or hold it with your pliers. Another way to enlarge a hole is to drill by hand with a slightly rough-cut piece of brass tubing of the desired diameter.

Always ask your mother's permission before you heat a nail red hot with her stove. Tell her that you will be doing the drilling outside the house because she knows that the smell of burned rubber or cork is much worse than that of burned toast.

As soon as you build up a good collection of corks and stoppers, they will begin to get mixed. Organize them by sizes or types on copper wires so that you can easily select the ones that you need.



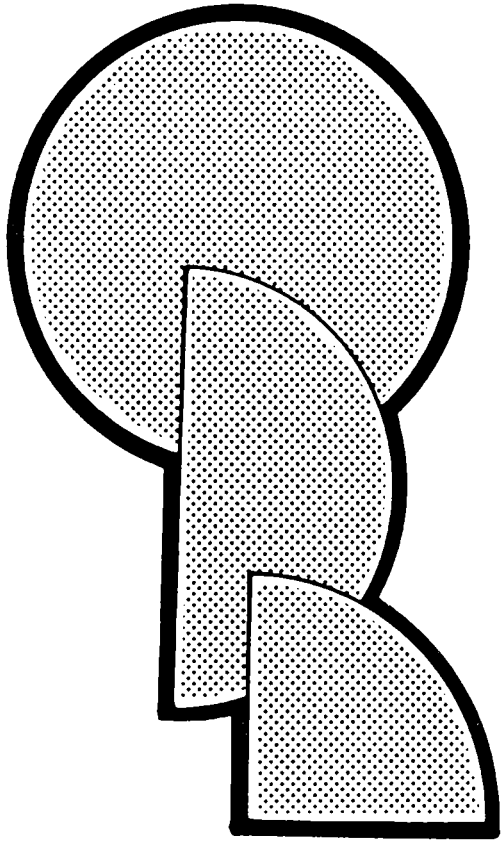
String stoppers on a wire

Filters

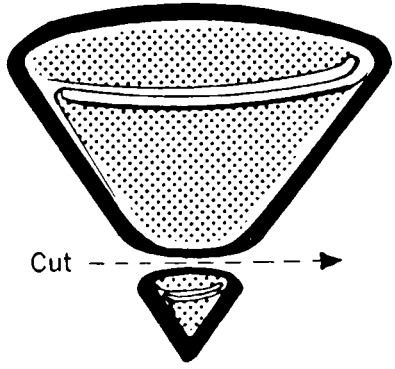
Make your own filters out of paper towels. The illustration to the left shows how to fold a standard round filter paper. Fold your paper towel in the same way. When you get to the third fold, tear it approximately round. You will be surprised how round it really looks when you form the cone by separating one fold from the other three folds.

A glass funnel is not needed for filtering with micro equipment. The cone fits into a beaker quite well if you wet it first. If the cone is leaned against a glass rod or even a pencil, it will drain faster.

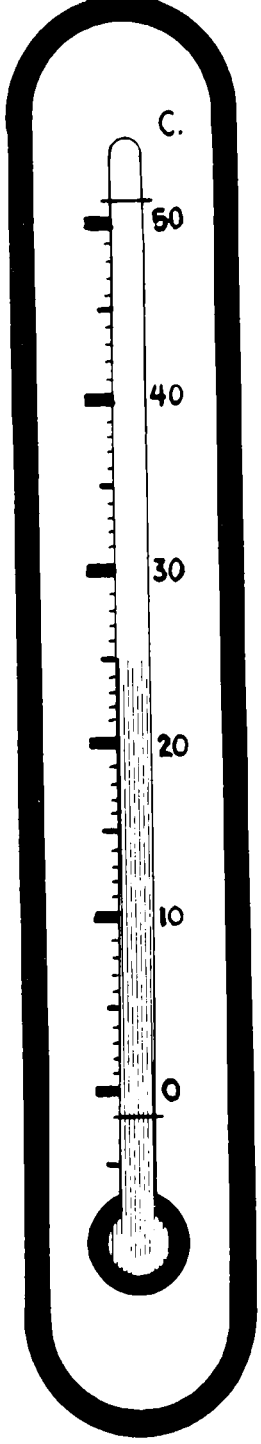
A powder funnel for pouring chemicals into micro bottles is made by cutting the tip off a filter cone.



How to fold a filter



Powder funnel



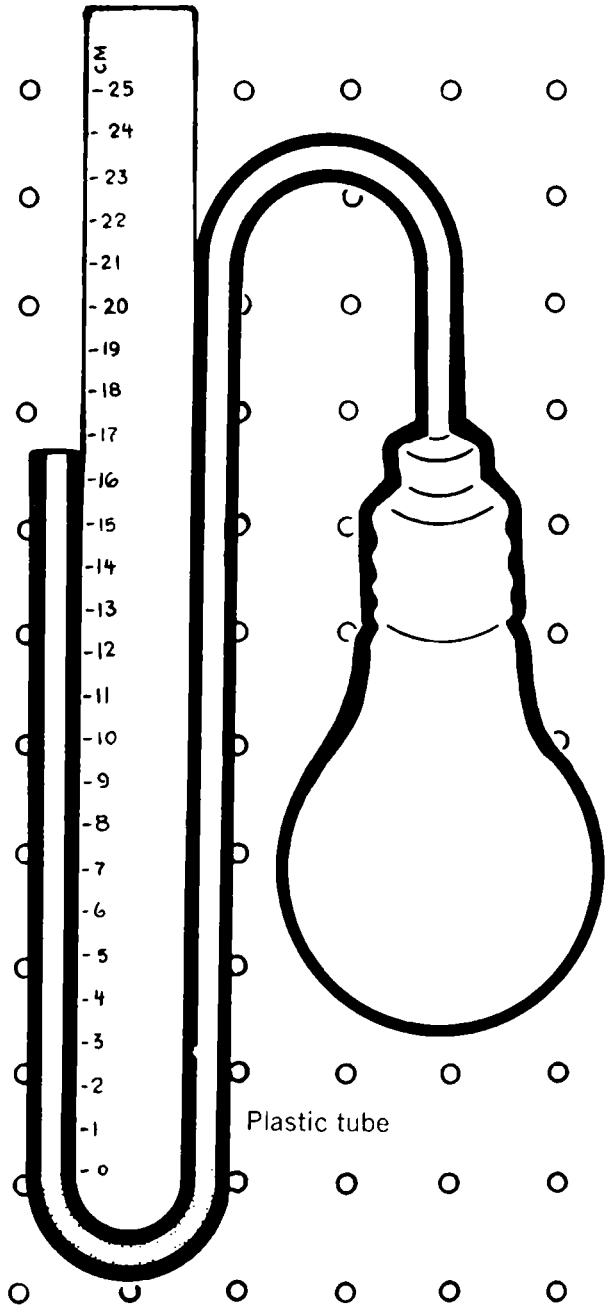
Thermometer on tongue depressor

Thermometer

Make your own thermometer. Take the thermometer tube from an old outdoor weather thermometer and mount it on a tongue depressor. Drill small holes with a red-hot needle, and wire it into place. You may be able to transfer the calibration marks directly from the old thermometer. If not, use another thermometer, and put both in increasingly warmer water to do the calibrating. Mark off the "tens," and space the remainder of the marks by eye.

The world's first thermometer was Galileo's air thermometer. You can make one if you have a test tube or a very small glass bottle and a long glass tube. You can calibrate it in the metric system by using ice water to indicate "0" for freezing and steam to indicate "100" for the temperature of boiling water.

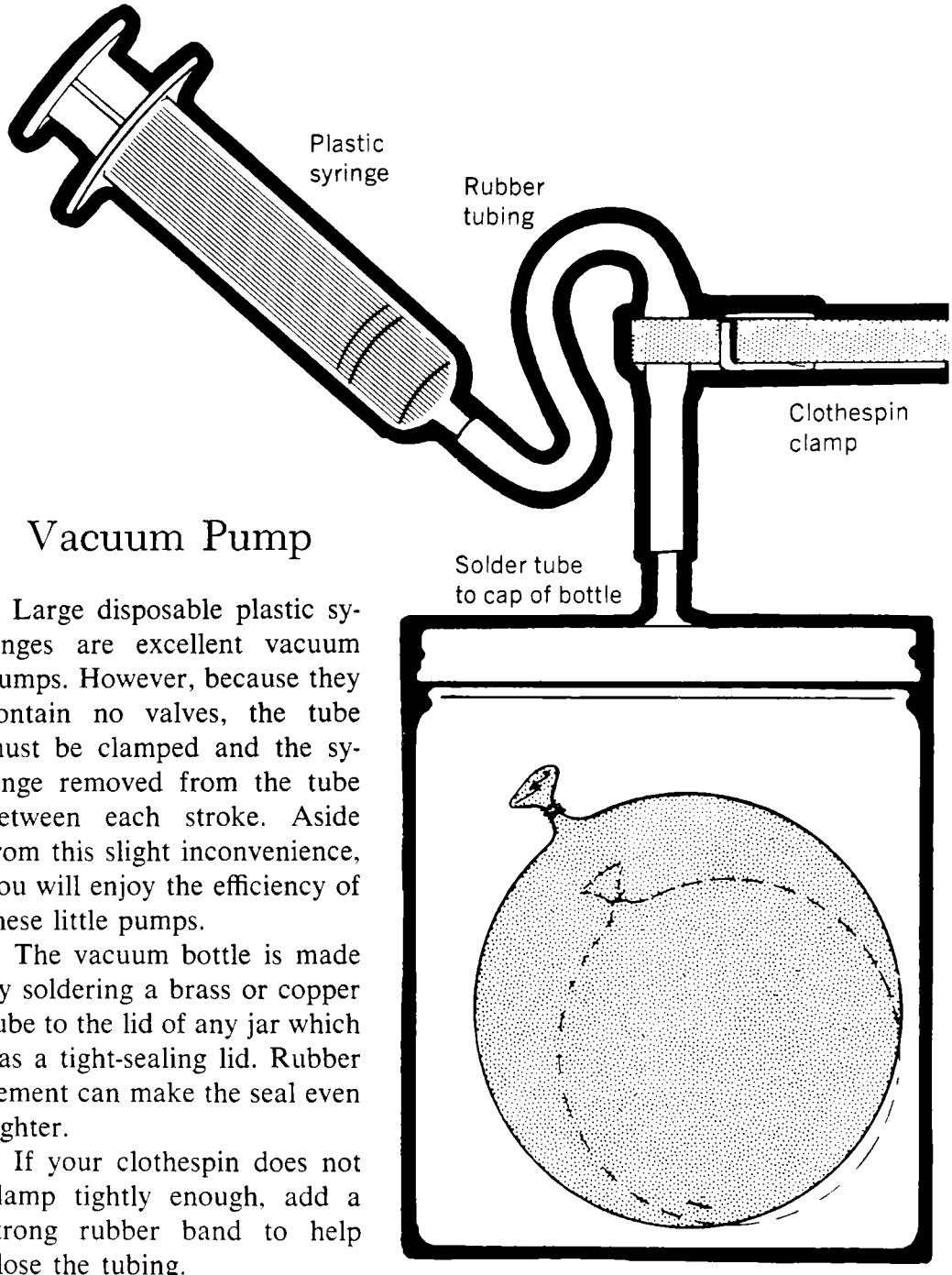
Build your own manometer on the experiment stand



Manometer

A manometer is an instrument used for measuring volume and pressure changes in gases or vapors. Plastic tubing enables even the beginning scientist to have his own manometer.

The manometer is a small amount of water in a U-shaped tube. When the gas in the container expands, it forces the water level to move. If the gas contracts and a slight vacuum is formed in the container, the water level moves in the other direction. The amount of change is recorded. A metric ruler is usually used to measure the change with this manometer. The manometer is fastened to the punchboard experiment stand. The thin-wall light bulb makes an ideal gas container.



Peanut butter jar vacuum chamber

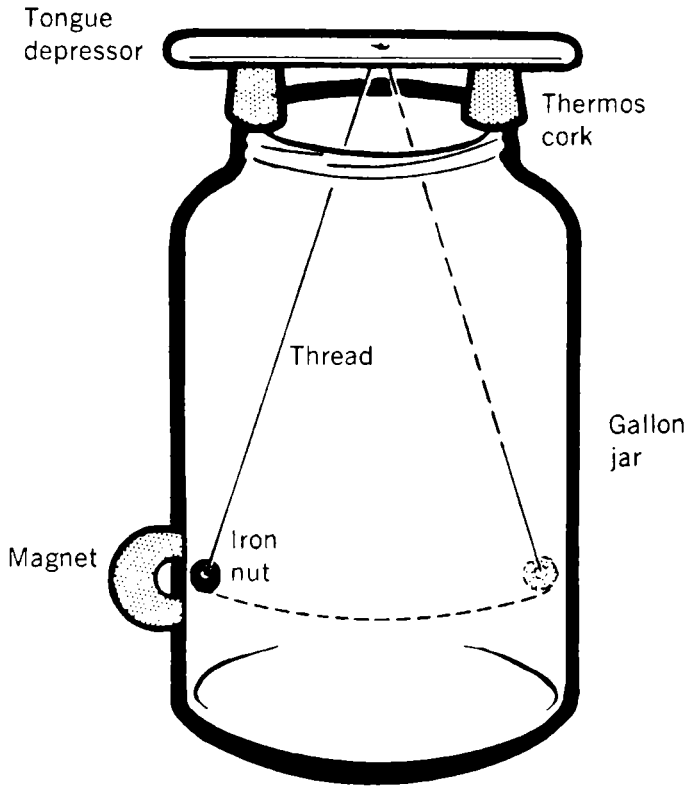
Vacuum Pump

Large disposable plastic syringes are excellent vacuum pumps. However, because they contain no valves, the tube must be clamped and the syringe removed from the tube between each stroke. Aside from this slight inconvenience, you will enjoy the efficiency of these little pumps.

The vacuum bottle is made by soldering a brass or copper tube to the lid of any jar which has a tight-sealing lid. Rubber cement can make the seal even tighter.

If your clothespin does not clamp tightly enough, add a strong rubber band to help close the tubing.

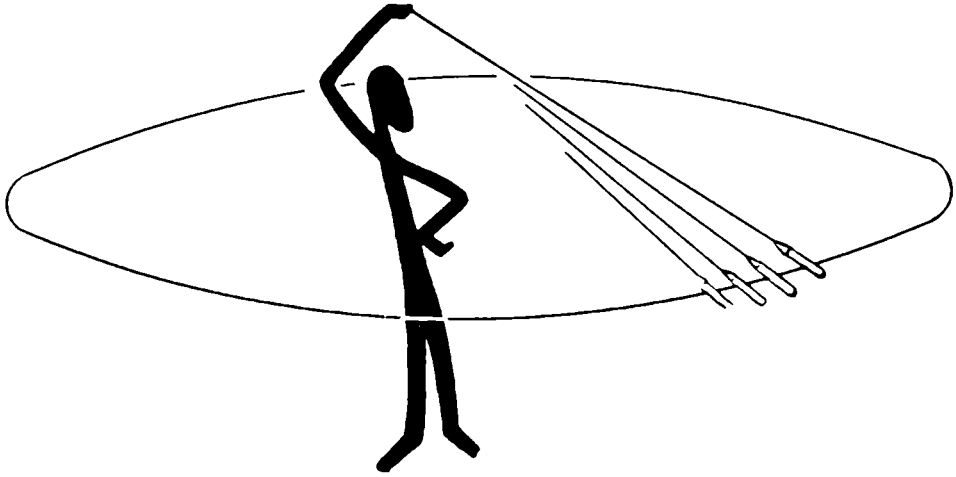
Gallon jar protects pendulum from breezes



Pendulum Timer

This is an extremely accurate timing device when it is adjusted well. The length of the thread should be almost 250 millimeters to make a period (full swing over and back) of one second. Check it with an accurate watch or clock. Each pendulum is slightly different, depending on the thread and weight which you use. Adjust it so that it will average sixty full swings per minute over a five-minute trial. Lengthen the thread slightly to slow the timer; shorten the thread to make it go faster. This is a split-second timer. You will be able to tell even the half- and quarter-second intervals. Can you read your wristwatch to the quarter of a second? Gallon jars (ask a restaurant manager to save one for you) are just the right height to support the pendulum timer and to protect it from air currents.

How does my centrifuge work?



the string

What new data do you think that nature would offer if I substituted rubber bands for the string?

If I used wire in place of the string?

Try longer (and shorter) string.

If I used lighter (and heavier) string?

If a scale were inserted in line with the string?

the centrifuge tube

If I substituted a balloon filled with water for the tube?

Use lighter (and heavier) tubes.

If longer (and shorter) tubes were tried?

the power hand

If I substituted a gun drill for the hand power?

If the tube were whirled slower (and faster)?

2 Using Your Microlab

Search for Truth

Science is a part of the great search for truth. A scientist insists on facing reality. He always would like to say, "I know," rather than to say, "I think." A scientist develops the courage to try even though he knows that his experiments may fail. People often are surprised to find that a scientist is happy because his experiment failed and because he found himself wrong. But the scientist knows that he is now closer to the truth. However, he is happier still when he can refine his theories and predictions after he has found his errors. A scientist is always willing to "try to see" in another way some hidden difference in the results of his experiments. A scientist keeps on trying until he feels that he has found the truth.

Learn to recognize the difference between data and theory. Data are bits of reality which are the true facts related to your problem. Theories are ideas that help control, predict, and explain.

Theories are your invented ideas. But just because you think out an idea does not make it true. Just because Einstein thought out a theory, he did not believe that made it true. Galileo, Newton, and Pasteur were always testing their theories, hoping to find some truth in them. Theories are merely useful devices of the mind which help us control, predict, and explain.

As you work with your microlab, try to generate new ideas about natural phenomena and to test them right away. That is why scientists have laboratories. They want to know now, not later, what the truth really is.

Change Something to Start an Experiment

Experimenting is associated with scientists and laboratories. But what is an experiment? Experimenting is changing something about an event or phenomenon to learn more about it. The change is made usually to help solve a problem. Experimenting is the most important operation of the scientist.

An experiment can do at least two things for you: (1) It always will give you data; and (2) it occasionally suggests a new theory about the cause of the event. Sometimes it will do both at the same time.

Concentrate on changes of properties and conditions to solve your problems faster. Young experimenters find that they get more action and get results faster if they concentrate on substituting objects with different properties or changing the conditions of the event under study.

A property is a characteristic, attribute, or quality which helps you identify an object. It is constant. It cannot be changed during the experiment. Specific gravity and inertia are good examples of general properties. Specific gravity is the ratio of density of any substance to the density of water. Inertia is the tendency to stay at rest or to stay in motion in a straight line. Elasticity, transparency, malleability, and ductility are examples of special properties of specific kinds of matter. Elasticity is the ability of matter to return to its form after being deformed. Transparency is the quality of being easy to see through. Malleability is when matter can be shaped or extended by hammering. Ductility is the property of matter which enables it to be drawn into wire or threads.

A condition is a variable which can be changed during an experiment or during a series of related experiments. A condition is a state of being. Solid, liquid, and gas states are conditions. A condition is one of the "more-or-less" things about an experiment. The temperature of an object can be changed during an experiment, as can speed, size, color, weight, position, and attitude, for a few examples.

Go to Extremes

Scientists often go to extremes when they change something to start an experiment. In this way they find out faster if the condition or property under study is significant. Be as extreme in your changes as you can with consideration for your safety and pocketbook.

Changing from ice water to boiling water might tell you quickly if temperature makes a difference. Changing the temperature of the water one degree probably would tell you nothing. A scientist would change humidity from very dry to very damp. After changing to lightest, a scientist would think next of heaviest. Longest would be followed by shortest. Smallest would suggest largest. Lowest leads to highest. And slowest would prompt fastest.

If any one of the conditions seems to be significant, the scientist may run a series of related experiments through the range of that condition to find the critical point at which it had its greatest effect on the event. If he found that temperature made a difference, he might look, for instance, for the exact temperature at which a substance starts to melt and change its shape. After finding that attitude makes a difference, a scientist might run a series of experiments to find the critical point at which the balance of forces is upset and an object falls off-balance. Experiments with models have already determined the critical point to which the Leaning Tower of Pisa must tilt before it will have to be chained off for the safety of visitors. The data from a series of experiments like these are usually recorded in graph form.

Go to extremes with properties also. Change objects with the lowest specific gravity to others with the highest specific gravity available. Transparency suggests opaqueness. Brittleness leads to elasticity.

Change something for a start in your experimenting. Note that "something" is singular. You must change only one thing at a time, keeping all other factors under control. If you made several changes in an experiment, you would not know which made the difference. And you would have to repeat each change one at a time.

Use Nature as Your Authority

If you really want to know what is happening in natural phenomena, go to nature, which is your best authority. Books always tell you what has happened in another event; nature can tell you what is happening in the event which you are studying. Books usually tell you what has happened under average conditions; nature can tell you what is happening under the conditions which you are encountering. When you have a problem, think to yourself: *Try to see.* Nature will offer some data which can be very helpful.

Learn to ask specific questions of nature. Specific questions are direct and to the point.

Scientists are very independent inquirers who have learned that nature, their best authority, can offer much valuable new data about what really happens in an event when scientists ask specific questions.

If you ask nature, "Why does an ice cube melt so fast today?" it cannot tell you. But if you ask more specifically, "What is the temperature of the air around the ice cube today?" nature will tell you the temperature (if you consult a thermometer). Learn to ask very specific questions so that nature can help you more.

When you ask dependent "why" and "how" questions of others, you are asking them to do the thinking for you and to tell you all about your problem. When you learn to ask very specific questions of nature, you are beginning to be an independent inquirer like a scientist.

Predict to Build Power into Your Ideas

Make a prediction every time that you make a change in your experimenting. Test your ideas against the truth every chance that you can get. State your predictions as specifically as you can before each event begins. Try to predict what will happen differently with each change in conditions and properties. In this way nature can help you separate what you "think" from what you "know."

Begin to use predictions to test your ideas as early as you can in each experiment. You should be predicting even before you can explain the event. It is not necessary that you understand completely before you begin to predict. A woman does not need to know all about the mechanics of her automobile to be a good driver. It is more important that she be able to predict correctly what to do next as she meets each emergency caused by changing conditions on a freeway.

The experiments suggested in the next chapter are worded to encourage you to practice predicting from the start of each experiment. A glance at Chapter Three will show you that there is a chance for prediction in every suggestion of a change for experimenting.

Ask *If . . . would* questions as you are searching for data. "*If* we make the air around the ice cube twice as warm, *would* it melt twice as fast?" You are inquiring because you don't know. You are asking nature for data.

As soon as you have some data about what controls the melting, your queries should change to the *If . . . then* form. "*If* we put the ice cube in water which is the same temperature as the air around it, *then* I predict that it will melt faster." Nature will tell you how near the truth your idea is.

Remember that it is not always necessary to gather a great deal of data first. Often you can start an investigation with a prediction based on past experience. Start predicting as soon as you can and predict as often as you can.

Keep a Lab Record of Your Experimenting

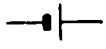
Record brief notes about your experimenting so that you can review your results with other interested experimenters. Record each change that you make. Use symbols and abbreviations as scientists do rather than write a story about each experiment. Be sure to be specific.

Start working on a problem in the way that comes most naturally to you. Most people start by collecting data. But this is not always the best way. Scientists often like to generate theories about the cause of the event first. Theories can tell you what kinds of data to look for and save time. Theories can guide the design of your experiments. If you have no data and if you have no theory, you can always start by experimenting. Nature may suggest something to you.

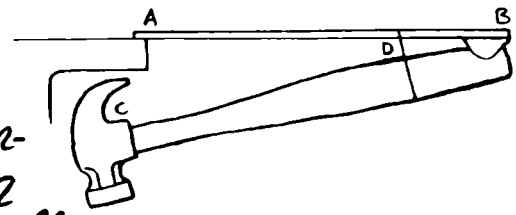
Your notes should indicate the relationship between data, theory, and experiment; they should show the order in which your ideas were developed and tested. Experiments always produce data. Occasionally they will suggest a theory to you. Remember that a theory is only your invented idea about the cause of the event. State it very briefly down the middle of the page.

The experiment notes of another young experimenter are shown on following pages. Can you tell what changes he made to start experiments? What data did he have to work with? What theories was he developing? How many times did he make predictions to test the power of his ideas? Did he discard any of his theories?

The next chapter is filled with interesting science problems for you. This book will not explain them to you because it is not intended to be an information book. The purpose of this book is to help you develop some tools, techniques, and strategies which will help you work more independently like a scientist. Generate your own ideas, and test them right away with the equipment in your microlab. You will know that your ideas are good when you can use them successfully for prediction.

V	verification
*	significant
it fell	data
will fall	prediction
ch	experiment
↑	rose or floated
→	moved to right
=	equal
>	more than
<	less than
s	solid
l	liquid
g	gas
G	gravity
gr	gram
	center of mass
	spin
exp	expand
contr	contract
	bounce or reflect
	vibration
cond	condense
evap	evaporate
	heat rising
	switch
	cell

Why do the ruler and hammer hang horizontally?



Jones, Jim

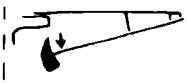
V = verified

↑↓ = up & down

⊐ = edge of table

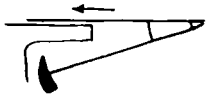
⟵ = hammer

(will fall) = prediction

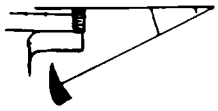
EXP.	DATA
6:40 p.m.	7-21
Nailed at "A" (cause)	V-No sign of nails or glue.
Magnetism	V-No metal on or under table.
Push "B"↓	Rocked up-down
Push "C"↓	 Rocked
Balance Lever Causes It	
Add clay wt at "B"	+ (RIGHT)
Add wt at "C"	+
Balance system on knife edge at "D"	would not balance
Change ends of hammer	(Won't work)+ Crashed Shot my theory down.

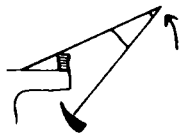
EXP. | DATA

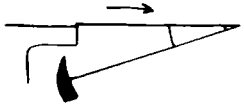
Position of wt. causes it



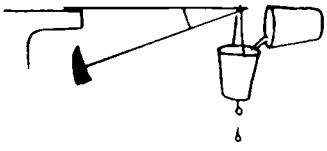
Did nothing

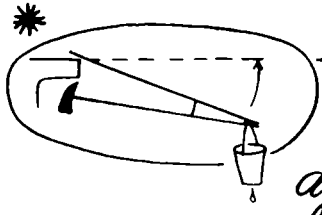




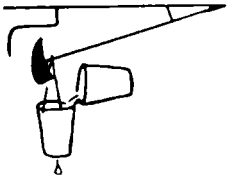


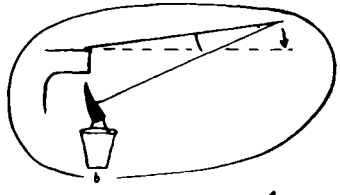
B↓ slightly





Sank. Then rose as water leaked out.





Did not make nearly as much difference.

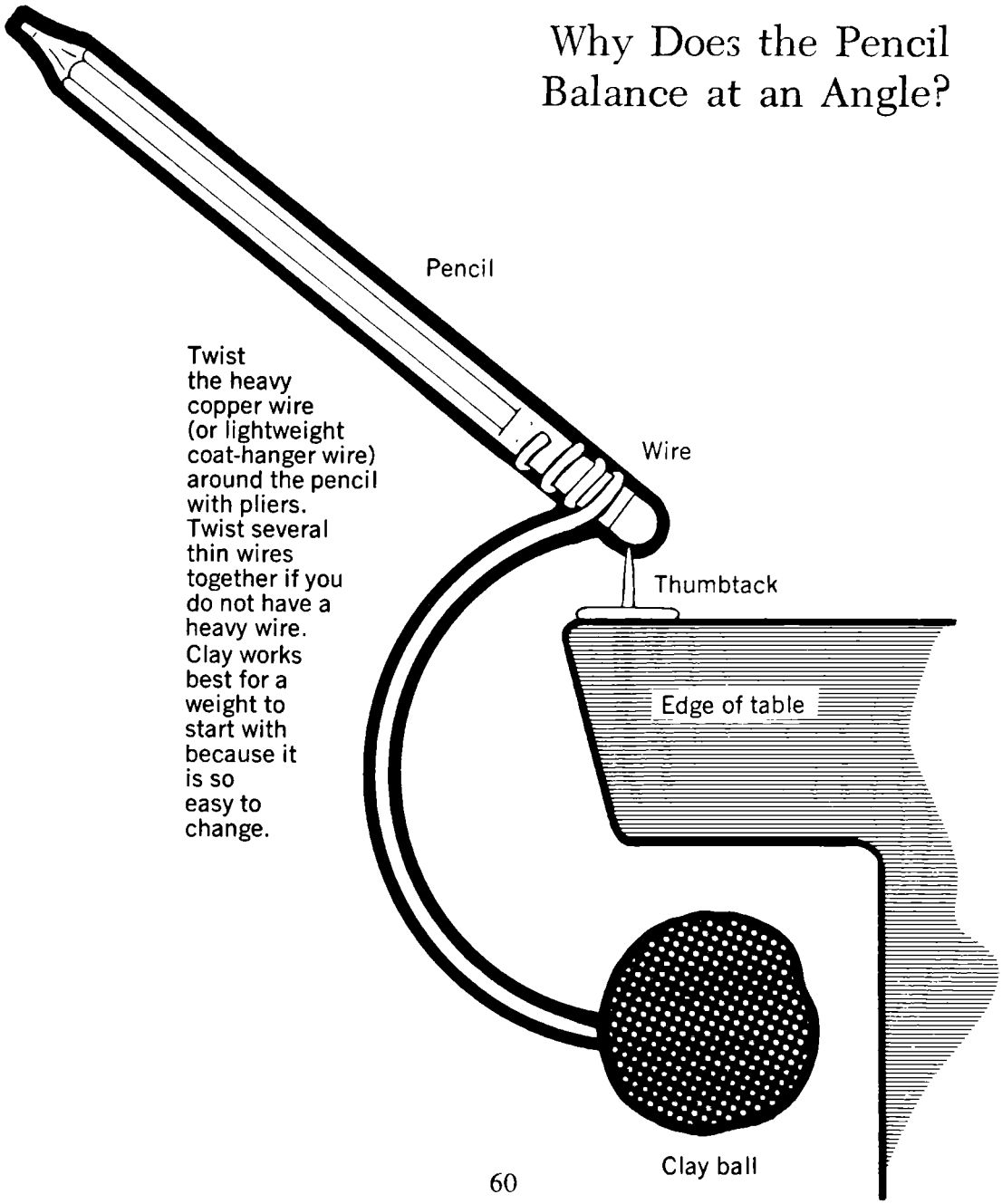
7:30 pm.

Tomorrow:

Try hammers of diff. shapes + wts.
Change to hanging fulcrum
Get protractor to measure change in angles.

3 Problems for Inquiry

Why Does the Pencil Balance at an Angle?


Pencil
Twist the heavy copper wire (or lightweight coat-hanger wire) around the pencil with pliers. Twist several thin wires together if you do not have a heavy wire. Clay works best for a weight to start with because it is so easy to change.
Wire
Thumbtack
Edge of table
Clay ball

the weight

If I substituted a foam ball (then a lead sinker), what new data would nature offer to me?

If I replaced the clay with a chain?

If, for a weight, I tried a plastic vial of sand (or water) that leaked during the event?

Try repeating the event underwater in an aquarium or in a swimming pool.

the support

Try to support the system on a finger instead of on the table.

If the pencil were raised and lowered on a tall thin rod?

If I repeated this event under zero-gravity conditions in space?

the pencil

If I substituted a glass (or metal) rod for the pencil?

If a flexible pipe cleaner were substituted for the pencil?

Use longer (and shorter) pencils.

If I added a wet small sponge to the pointed end of the pencil?

the wire

If I substituted a chain or a cord?

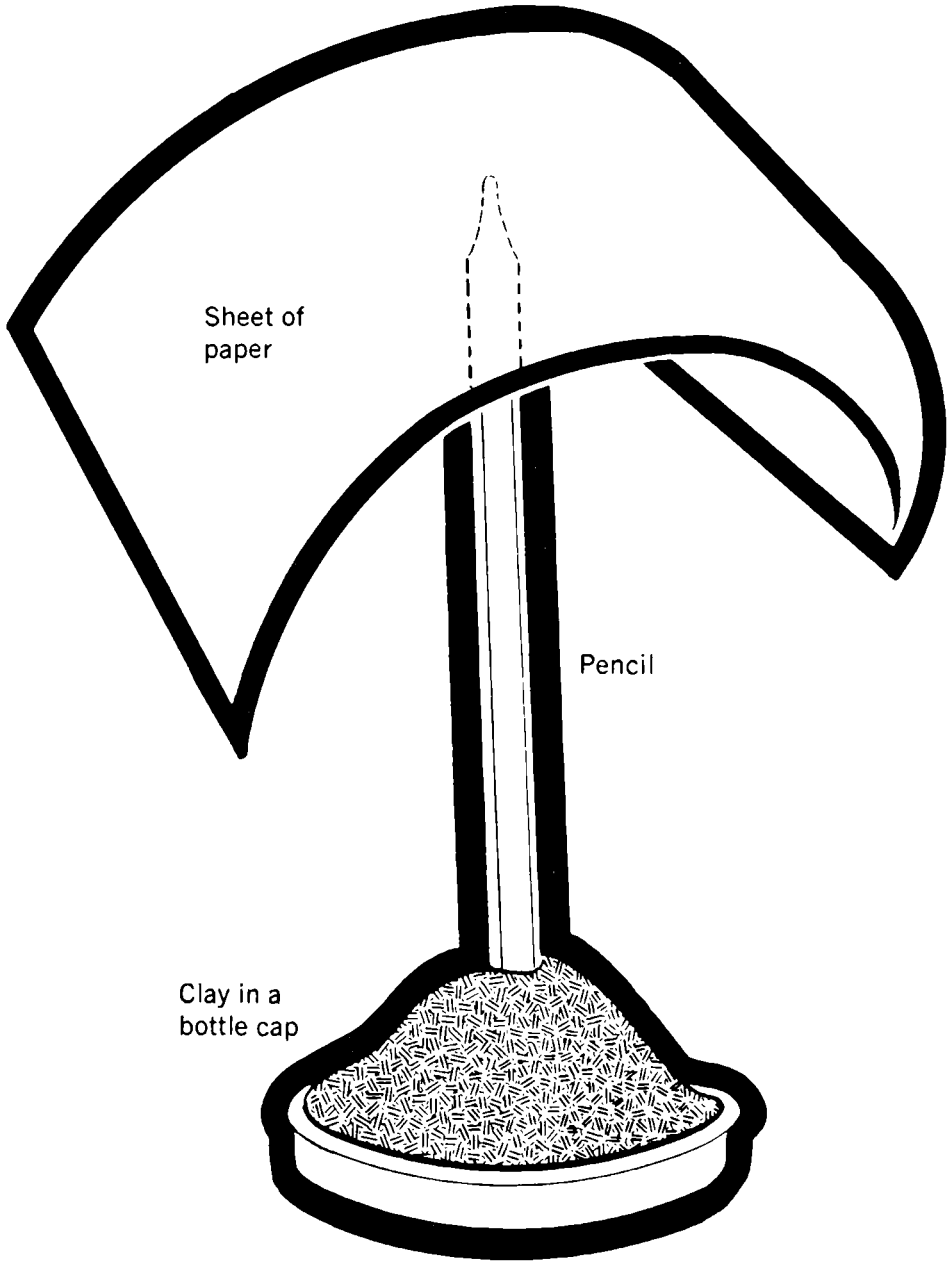
How about replacing the wire with a stiff curved band of metal?

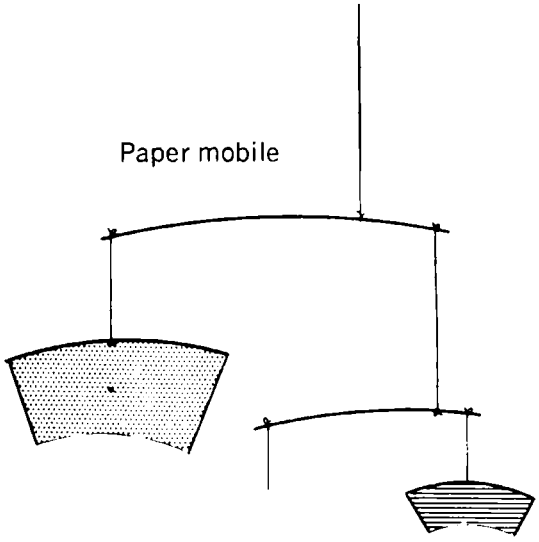
If the wire coil were moved closer and closer to the middle of the pencil?

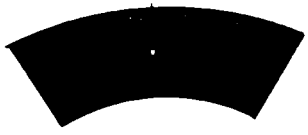
What are the most significant variables which you have discovered during this series of experiments?

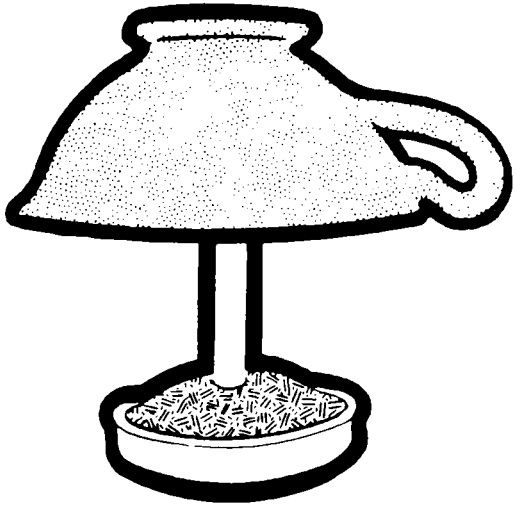
Why is it so easy to balance a sheet of paper on a pencil point?

And why is it so hard to balance a note card?









the pencil

If I made a mobile by hanging horizontal flat sheets of colored papers on broom-straw or coat-hanger beams?

If my blunt fingertip were substituted for the sharp pencil?

the sheet of paper

If I substituted a teacup for the sheet of paper?

If I compared flexible and stiff papers, what new data would nature offer to me?

If the distribution of weight were changed by folding the paper on one side?

If I added weights such as paper clips and clay?

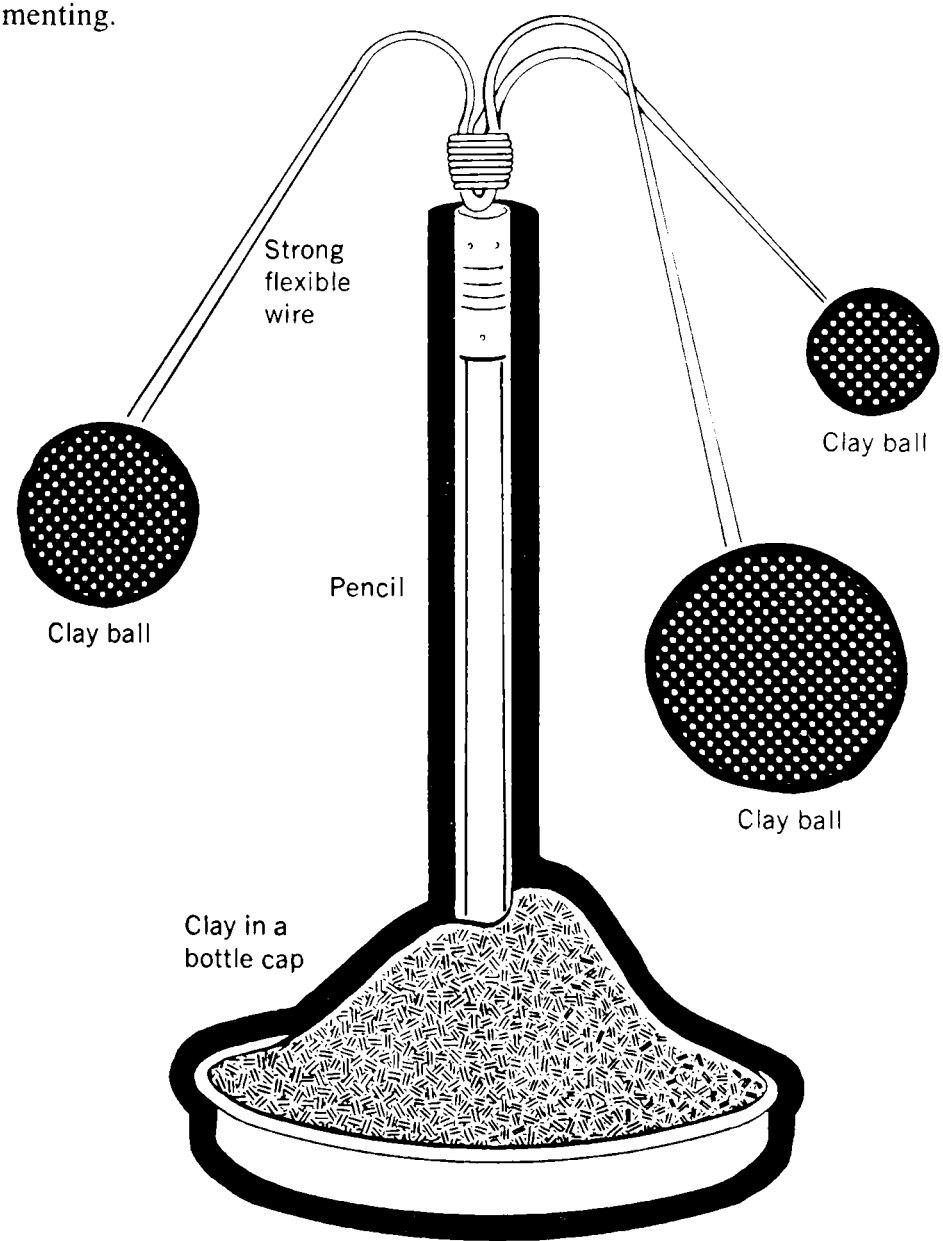
If I substituted the note card and bent it downward like a gabled roof (then upward)?

Substitute a sheet of aluminum foil for the paper.

What other variables can you think of to change?
Remember to keep control by changing just one variable at a time.

Why do the three balls balance so well in almost any position?

Clay in a bottle cap makes a fine supporting stand for many experiments. The three wires are soldered or wired together securely. Clay balls are best for weights because they are easy to change for experimenting.



the clay balls

What new data would nature give me if I substituted rocks (and feathers) for weights?
If I removed one of the balls (then all of them)?
Try five balls and wires instead of three.
If I placed one weight closer (then farther)?
If I placed the weights lower (then higher)?
Put the system into a spin.

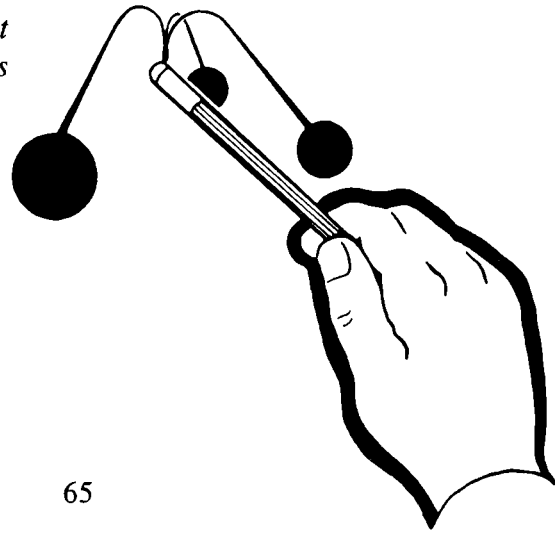
the wires

If I substituted cord for the wire?
If stiff rods were used in place of the flexible wire?
If I did it underwater in a swimming pool?
If iron weights were used and magnets were brought near them?

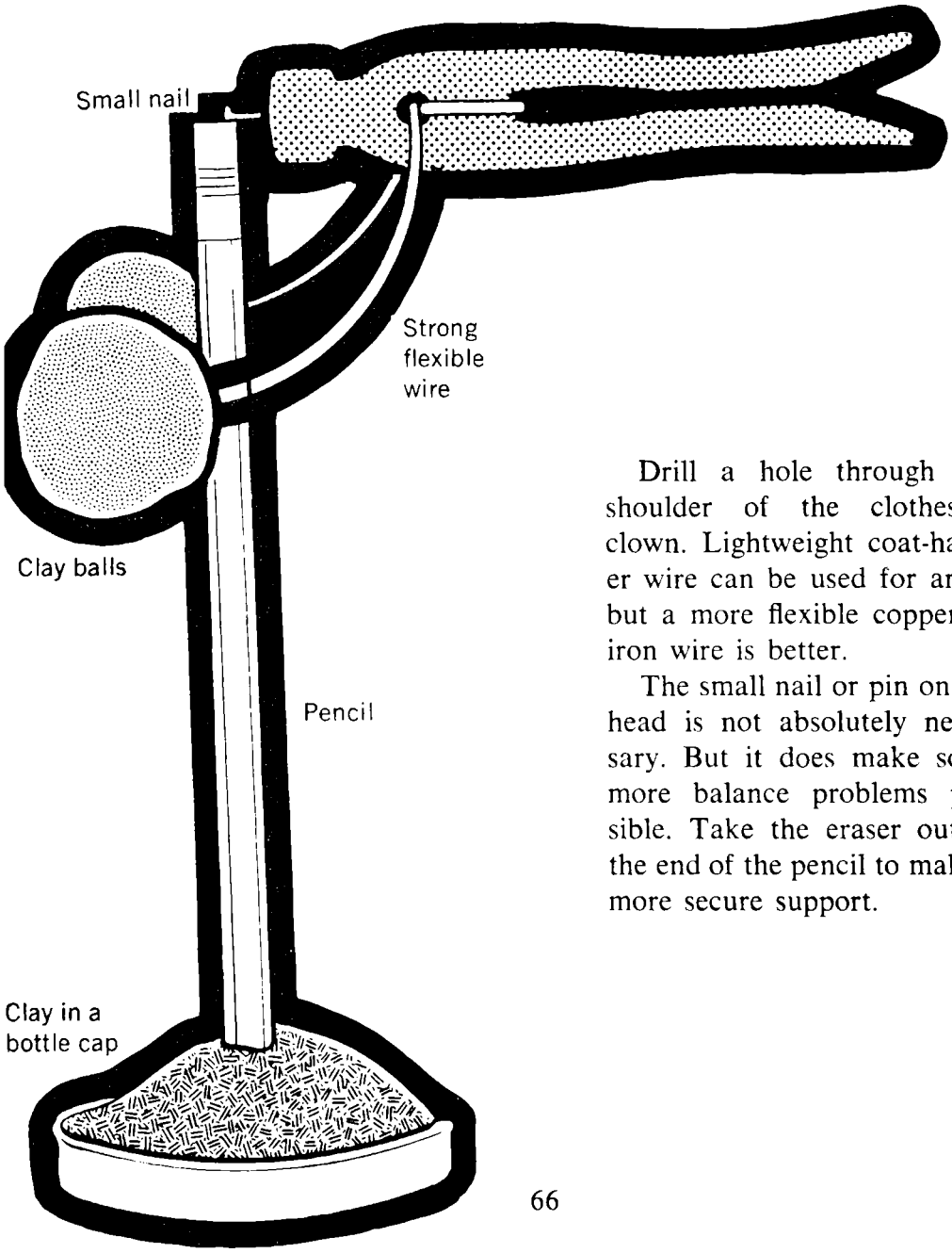
the support

If I held the pencil in hand?
If I jumped off a step with the system balanced on my fingertip?
If the pencil support were leaned at an angle?

Which properties were most significant to the success of this event?



Why does the clothespin clown balance horizontally?



Drill a hole through the shoulder of the clothespin clown. Lightweight coat-hanger wire can be used for arms, but a more flexible copper or iron wire is better.

The small nail or pin on the head is not absolutely necessary. But it does make some more balance problems possible. Take the eraser out of the end of the pencil to make a more secure support.

the weighted arms

If I used a chain instead of a wire for arms?

If the weight of the hands were made more dense like lead (or less dense like styrofoam)?

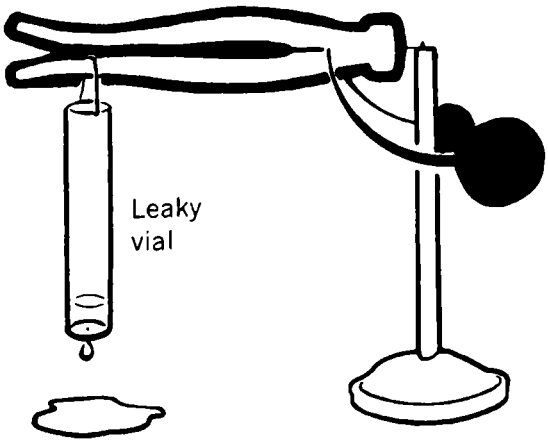
If the arm wire were just put through the single hole instead of being twisted around?

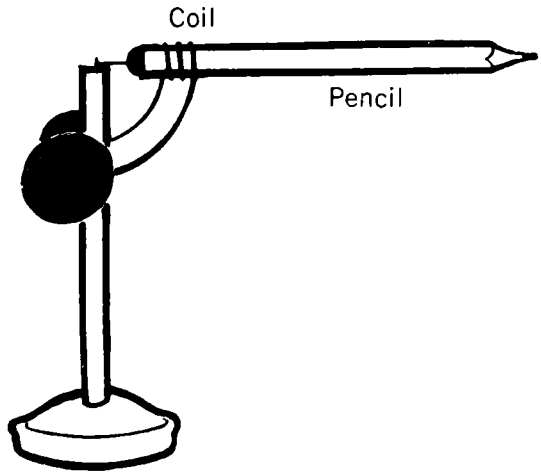
If I thrust the arms forward (then backward)?

Move the arms wider (then closer).

If the arms were bent higher than the body?

If I used a vial of water for a weight and let it leak during the event?





the clothespin body

If I made the body shorter (and longer)?

If I substituted a pencil for the clothespin body?

If a clay weight were added to the foot end?

the support

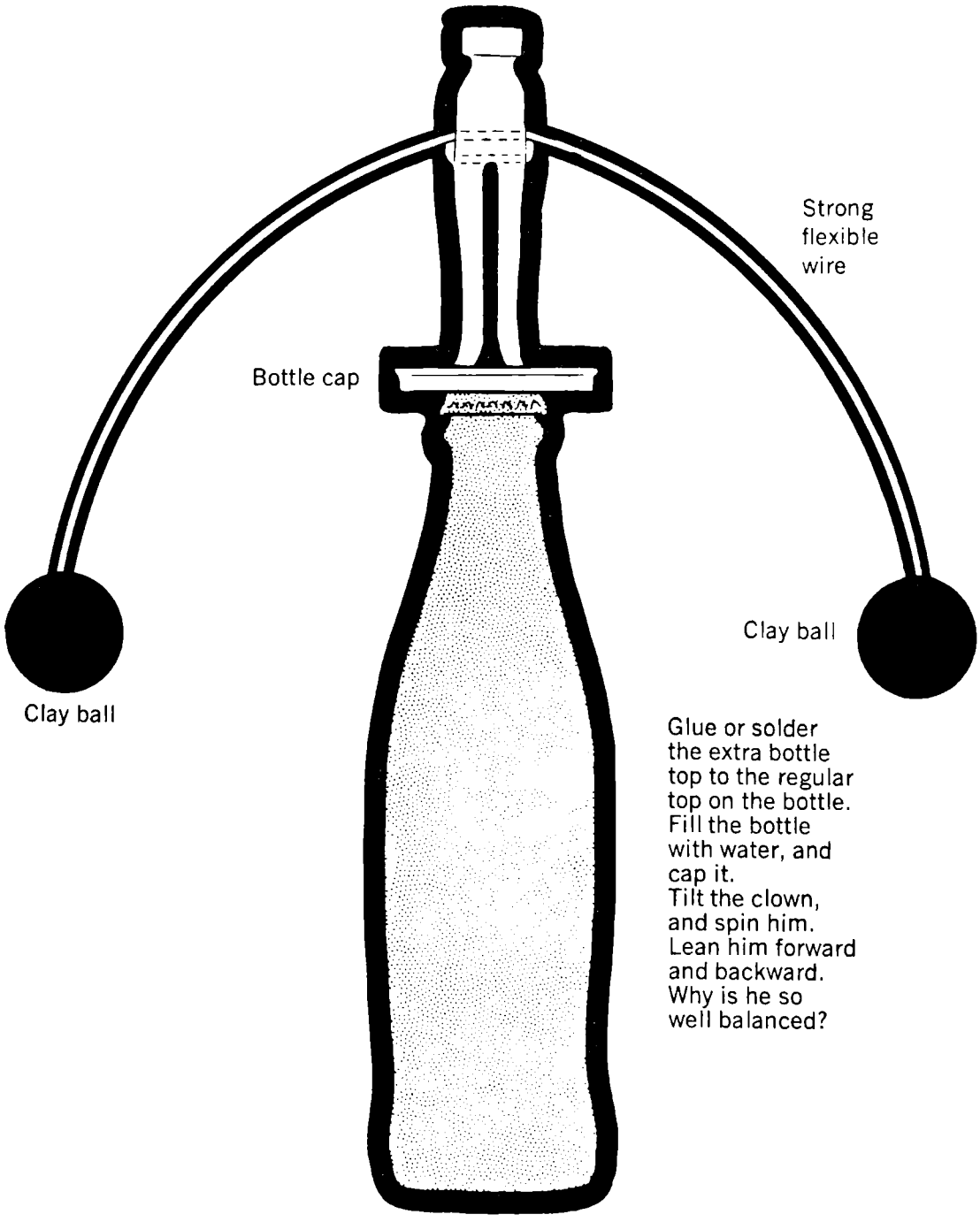
If I tilted the support during the event?

If the support were made much taller?

Use a finger for the support.

If I tied the leaky vial of water to the feet?

Why does the clothespin clown balance so well when you turn him around?



Glue or solder the extra bottle top to the regular top on the bottle. Fill the bottle with water, and cap it. Tilt the clown, and spin him. Lean him forward and backward. Why is he so well balanced?

If I wrapped the wire around a pencil instead of the clothespin?

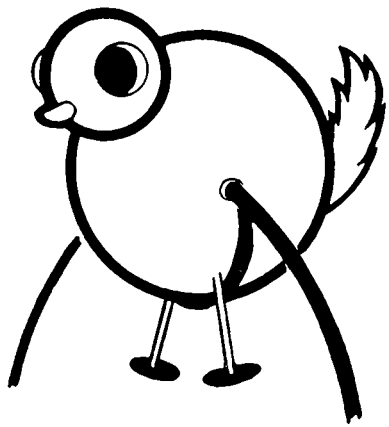
If the clown were balanced on a finger instead of a bottle?

Substitute foam balls for the clay weights.

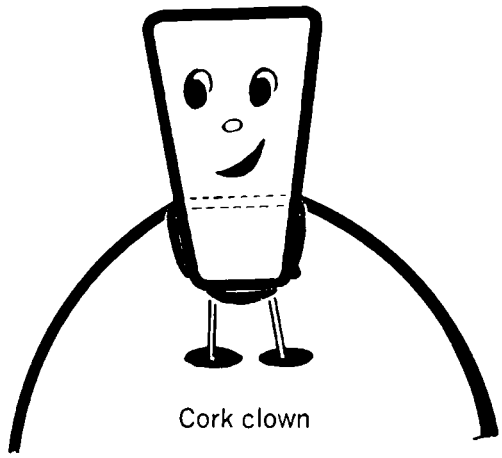
If I eliminated the weights entirely?

If very dense fishing sinker weights were used instead of the clay?

If I used stiff rods for arms?



Styrofoam gooney bird



Cork clown

If I bent the arms upward and stood the clown on his head?

Bend the arms forward (and backward).

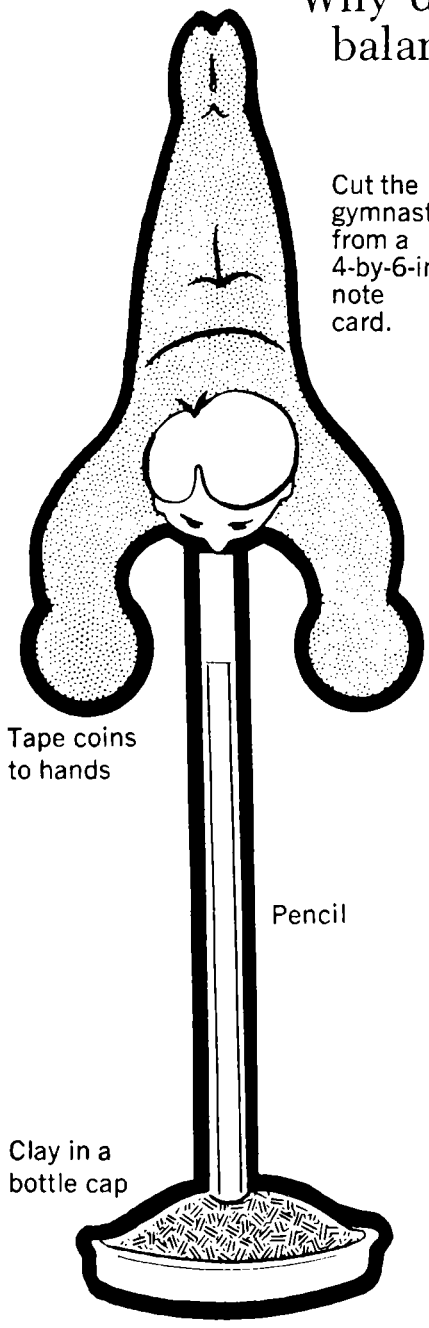
If I brought the weights closer (and farther)?

If the arm wires were put loosely through a single hole?

If I nailed a bottle-top support on a long stick and raised the clown high?

If I blew air on the clown with a fan and moved the fan closer (and farther)?

Why does the gymnast balance so steadily?



If I cut the gymnast out of writing paper instead of note card paper, what would nature tell me?

If a finger were substituted for the pencil support?

If I added paper clips or clay weights to his feet?

Add a little weight to his front side (then to his back side).

If I made the support much higher with a long stick or at least a broom handle?

If one hand were weighted more than the other?

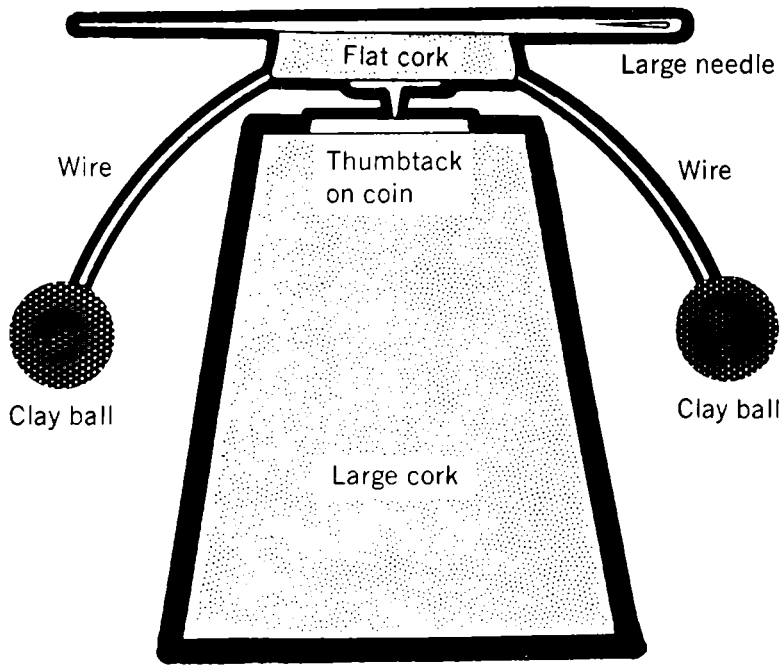
Blow air against the gymnast as he balances.

If I walked up steps with the gymnast on a finger?

What other cutouts could you make to balance? A frog? A butterfly? A bird? An elephant?

Why is the compass needle so sensitive?

Make a compass needle by stroking it in one direction with a single end of a magnet. Glue thumbtack to cork.



If I substituted a small alnico magnet for the needle?

Remove the weights.

If another material were used in place of the top cork such as clay?

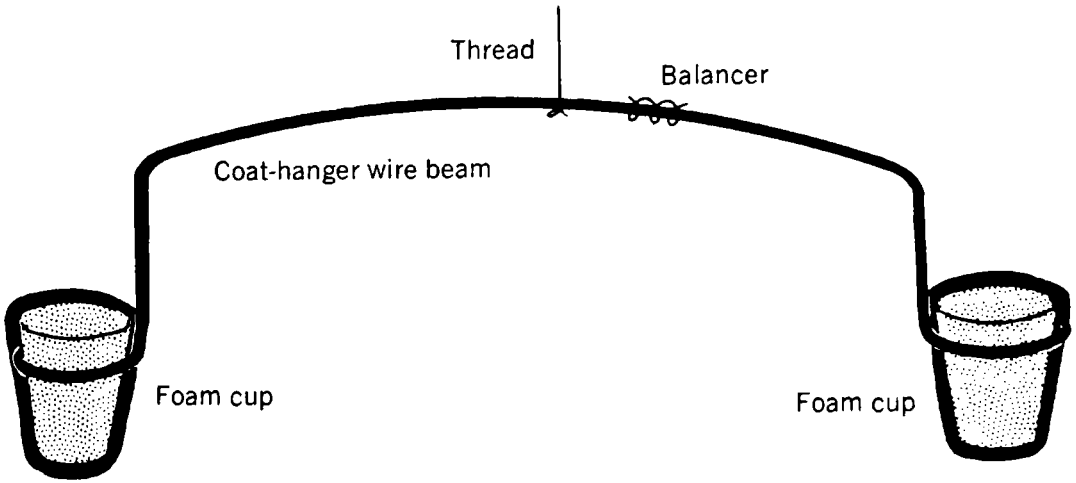
Bring another magnet near the needle.

If I moved the weights farther apart (and closer together)?

If a tall pin were used in place of the thumbtack in the top cork?

How can this scale be made more sensitive?

It was set up for convenience of use, but it is not very accurate or sensitive.



If I substituted a wood dowel?

If a broom bristle were substituted for a beam?

If the beam were straightened?

Try longer (and shorter) beams.

If I hung the weights from bends or loops so that they could hang freely?

If I tried using lighter (and heavier) weighing cups or pans?

If I bent a slight inverted V for a fulcrum on the beam?

Use a metal bookend to support the beam in place of the thread.

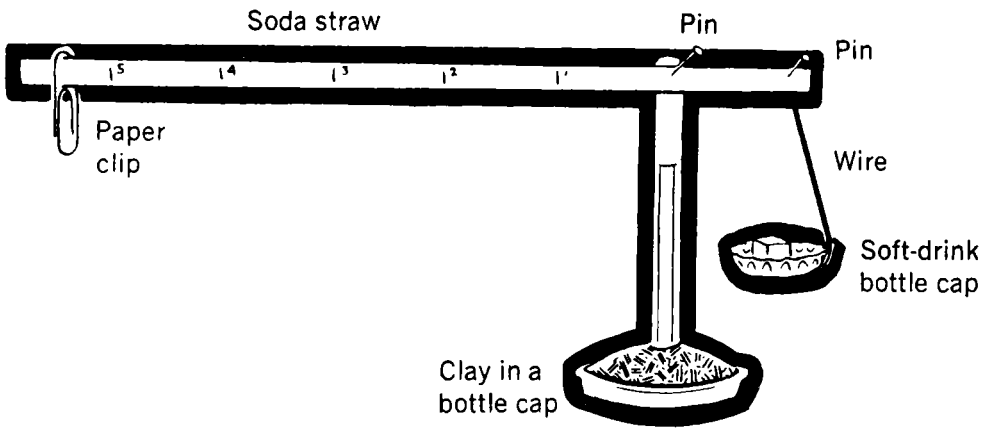
If I used a knife-edge support made by taking the eraser out of a pencil and flattening the end of the eraser holder with pliers?

Use a hanging platform for the weights instead of a cup or a cone.

Which variables did you find most significant?

What other changes were you able to make?

Why does this off-balance-looking scale balance light objects so well?



If I substituted a chopstick for the soda straw, what new data would nature offer me?

Use an electronic miniclip for the paper-clip slider.

If I replaced the bottle-cap weighing pan with the bottom of a foam cup?

If weights were tied on a string instead of putting them in a cup or on a pan?

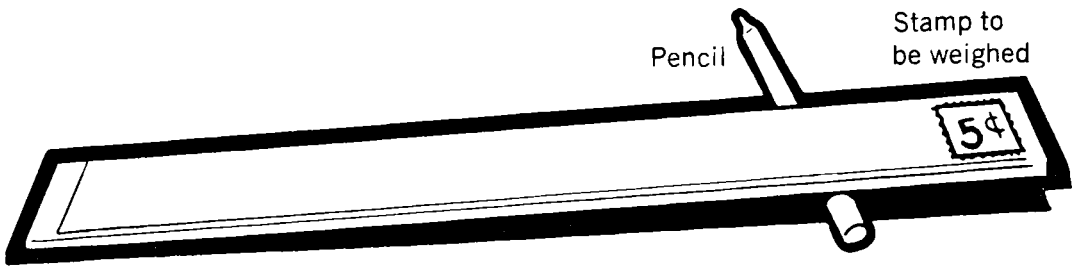
Make the weighing pan hang stiffly instead of letting it swing freely.

If I made the support lower (and higher)

What other experimental changes can you think of to try?

Did you try to predict the outcome of these changed events?

How can I make my roll scale more sensitive to lightweight objects?



If I removed the tape?

Use a shorter (and a higher) fulcrum.

If a smaller (and a larger) fulcrum were used?

If I used a triangular file for a fulcrum?

If I used a knife-edge for a fulcrum?

Change to a plastic ruler.

If a paper U beam were used?

If I used a paper L beam?

If I tapered the long end of the beam?

If I weighed a stamp (a feather, pin, hair, etc.)?

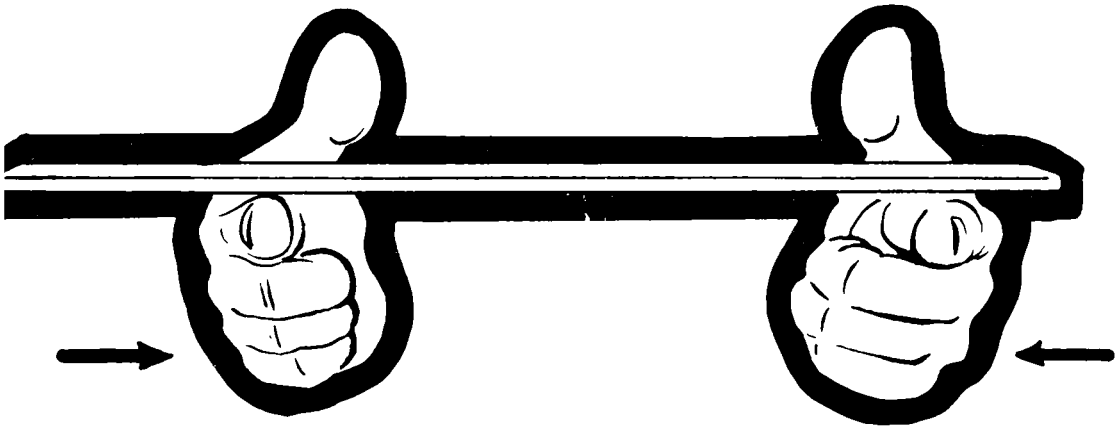
Breathe on one end of the beam.

If the weights were hung from the short end instead of standing them on the beam?

If I protected the scale from air currents by experimenting in a cardboard box?

Have you been practicing prediction with each experimental change?

Why does the stick seek and find its own center?



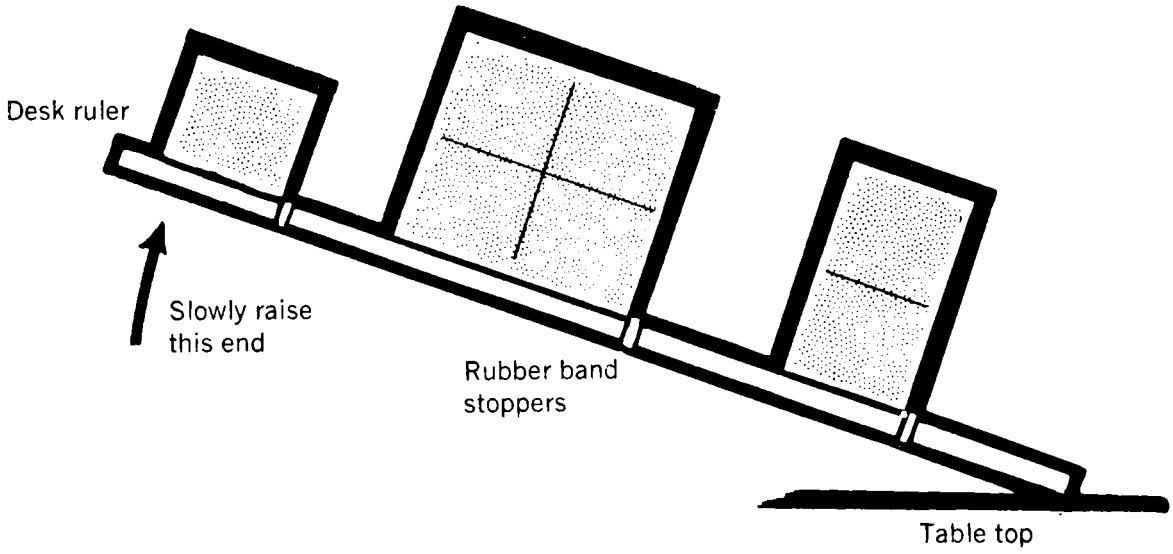
the supports

If I used two pencils instead of fingers?
(And how about two chairs? Two spools? Two flashlights?)
If rolling devices were substituted for sliding supports?
If I put the stick overhead where I couldn't see it?
Reverse the event by starting in the middle to move outward.
If I start my fingers at different places each time?
If I wrap one finger with sandpaper and put Vaseline or butter on the other?

the stick

If I used a baseball bat in place of a stick?
If I did this in a swimming pool and slid my fingers along the top of the stick?
If a board were substituted for the stick?
Also try a box, a broom, and a book.
If I used a curved stick like a bow?
If I added weights to one end of the stick?

Why do the blocks always topple in the same order?



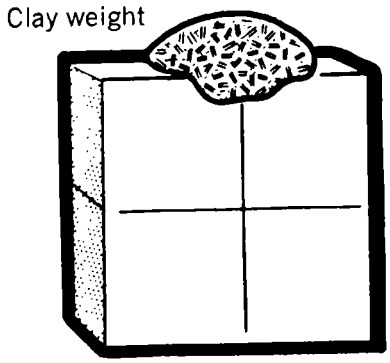
Put small rubber bands around the ruler so that the blocks must tumble, instead of sliding into one another. Place the blocks on the flat side of the ruler, and raise the end very slowly. One block will always topple first. The other two will tip over at approximately the same time, instead of falling separately as expected by most people. Keep the blocks in the same order and repeat several times. It helps to refer to the blocks as the one-unit, two-unit, and three-unit blocks. The units are made by gluing any toy blocks together. A board is used with very large blocks instead of a ruler.

the ruler

If I tipped the ruler over the edge of the table instead of lifting it?
If a wide, thin board were substituted for the ruler?
Lift the ruler very slowly (and very fast).
If I started slowly and then speeded up the lift?
If I removed the rubber bands?

the blocks

If I changed the order of the blocks?
If the blocks were laid flat instead of on end?
If the blocks were laid on their edges instead of on end?
Place the blocks standing on end but crossways instead of facing the edges down.
If a large clay weight were added to each block in turn?

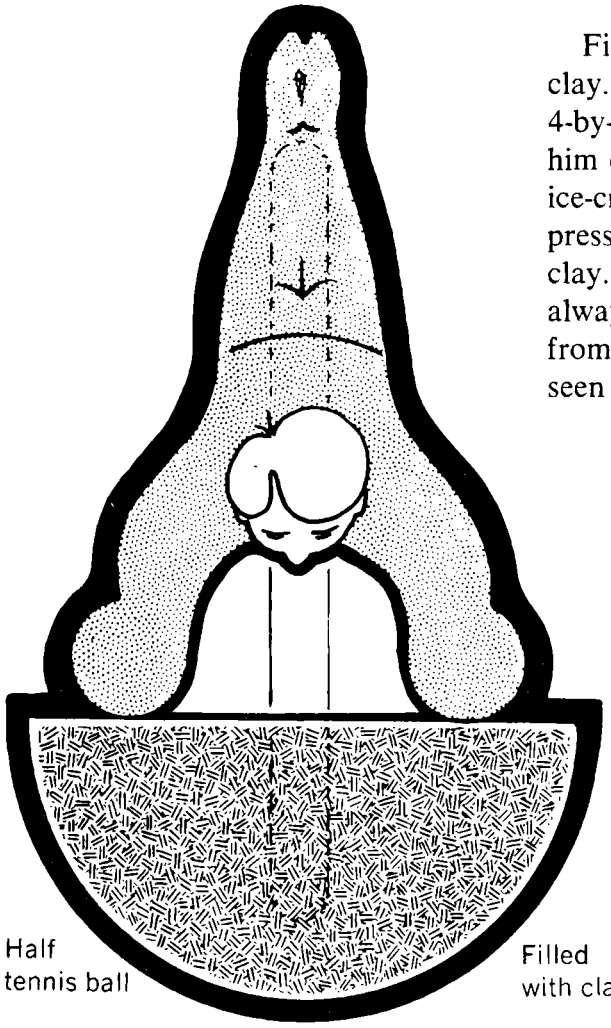


Which variable was most significant?

Did you discover any new variables to manipulate?

Did you think of control during your experimenting?

Why does the gymnast always come back to the handstand position when moved?



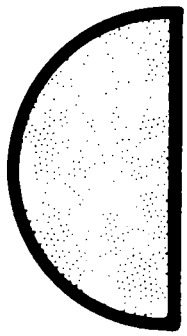
Fill a half tennis ball with clay. Trace this gymnast on a 4-by-6-inch note card, and cut him out. Glue him to a pencil, ice-cream stick, or tongue depressor, and stick him into the clay. Push his feet over. He will always come back to balance from any position. Have you seen toys which work like this?

the half ball

Try a lead half ball.

If I eliminated the weight and glued the support to the bottom of the half ball?

If I put a foam half ball on edge, what new data will nature offer?



If I filled the half ball partly with water and covered it?

If the half ball were balanced sideways on the sharp edge of a ruler?

Use a smaller (and larger) half ball.

If I put the balanced system on a book and turned it around and around, adding centrifugal force to the system while holding it?

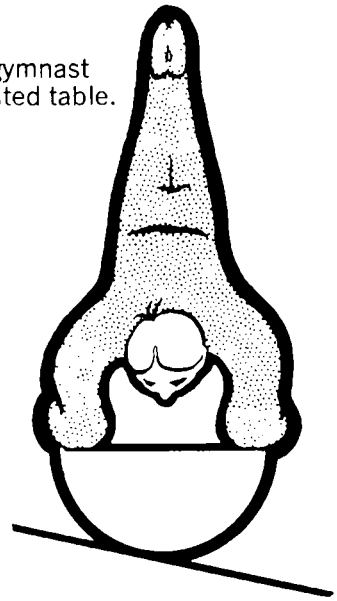
the gymnast

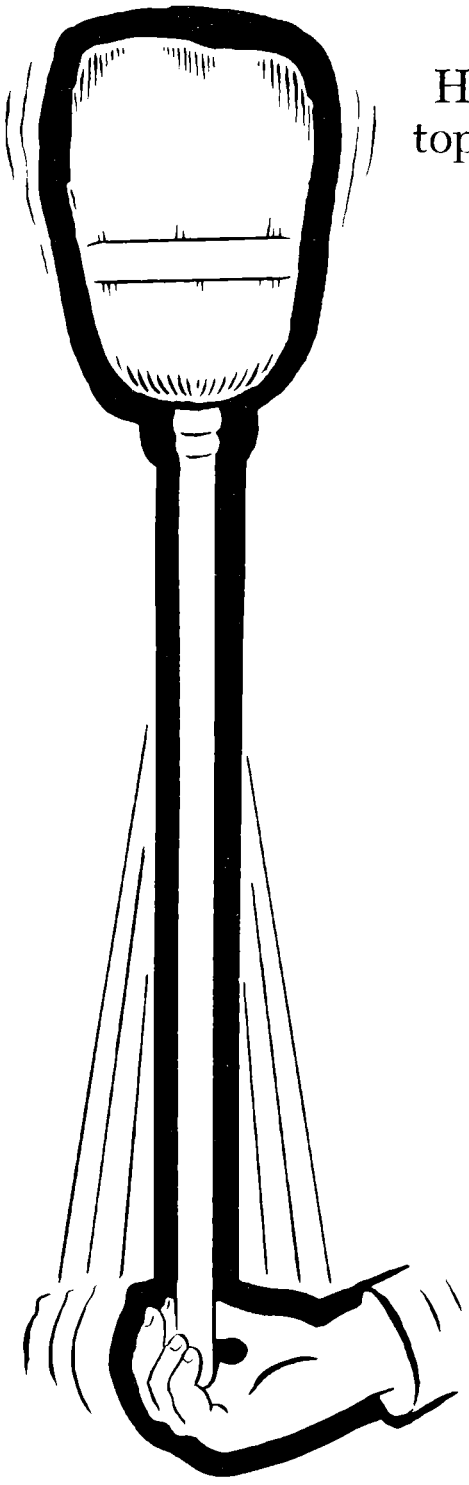
If the gymnast were eliminated from the ball?

If I substituted a note card sail, frog, butterfly, etc.?

If I added a clay weight to the gymnast's feet?

Put the gymnast on a slanted table.





How can jugglers balance top-heavy objects so easily?

Most people like to place the weight low for stable balance. Jugglers, therefore, are amazing when they work so effortlessly with the weight high. How can they do this? You, too, can be a juggler once you learn the principles of science which make them successful. Wouldn't you like to ride a unicycle, walk on tall stilts, or balance a broom upside down?

The fastest way to learn is to experiment, to build theories, and to test these with predictions.

If I tried this more safely with a ball of clay stuck on a long coat-hanger wire?
(Bend loops on both ends of the stiff wire.)

If I removed the clay and tried this without the weight, what new data would nature offer to me?

If the clay weight were put down near the bottom?

Try styrofoam in place of the clay.

If I made the support higher (then lower)?

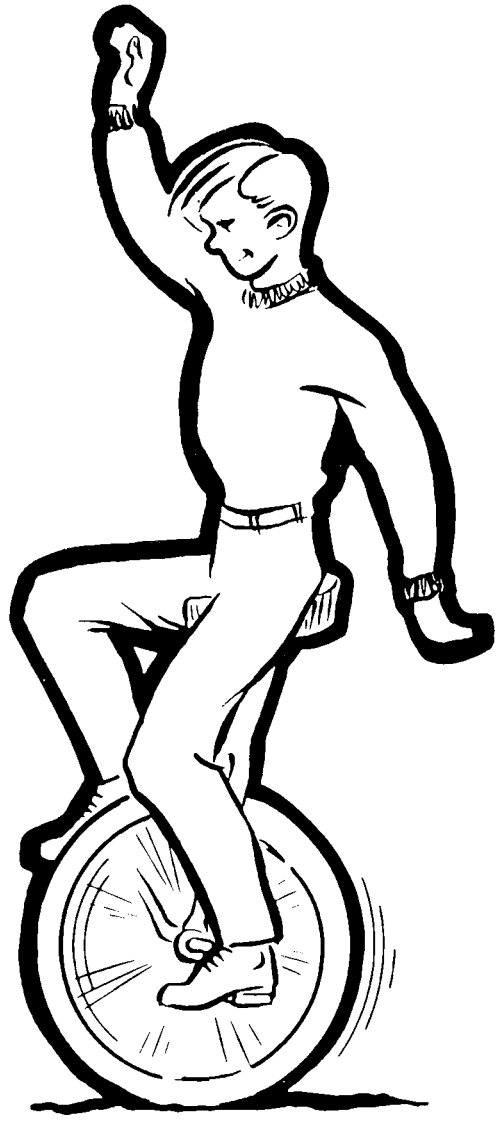
If the support were limber rather than stiff?

If I used a round hoop instead of a stiff wire or broom?

If I tried being the weight to be balanced by walking on tall stilts?

If a strong breeze came up during the event?

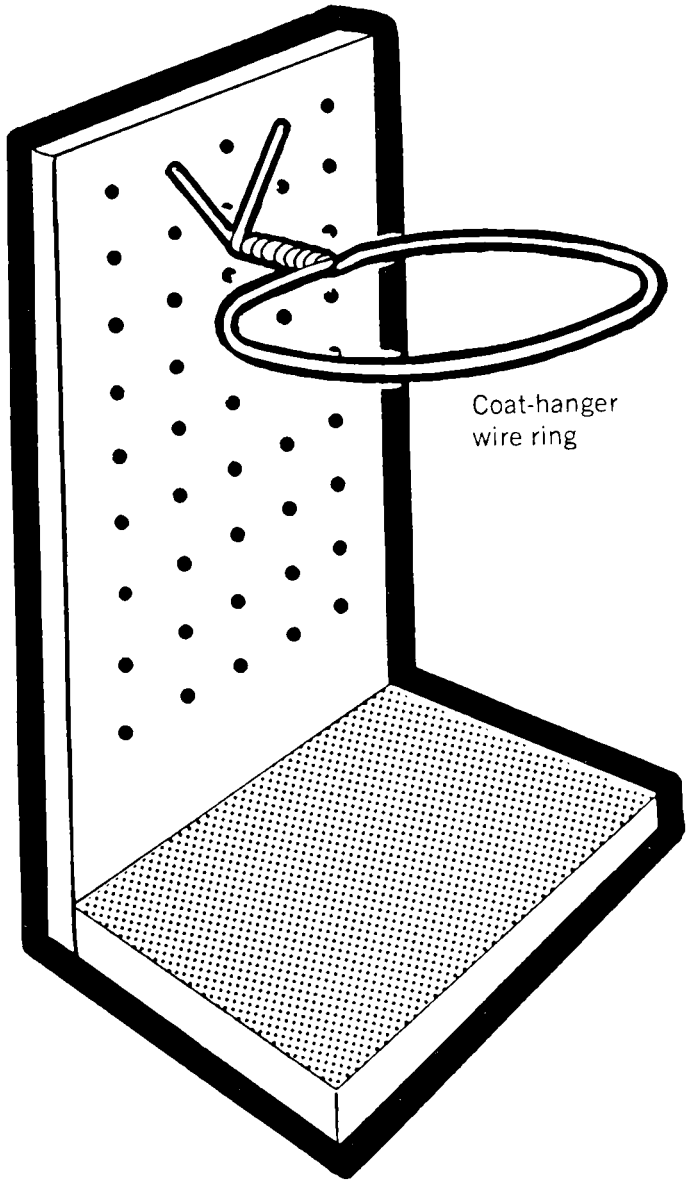
Why not try to balance your own weight with a unicycle?



Use an unstable liquid weight like water in a foam cup instead of the solid clay or broom.

If I used a wire support bent into the shape of an inverted V?

Where is the center of mass of your experiment stand?



Knowing the center of mass of your equipment will help you keep it in balance and will also help you prevent accidents.

If I gently slide it to the edge of the table in a least three different positions?

Balance it over a pencil in each of the three dimensions.

If it were hung from at least three different corners?

Use a plumb bob to double-check.

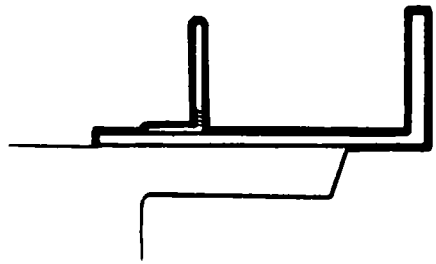
If I took each section apart and found the center of mass of each and then averaged them? Add weight at various places.

If I tried to balance the stand on its center of mass?

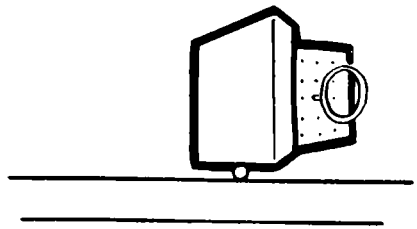
Try to spin the stand on its center of mass.

If the ring were removed?

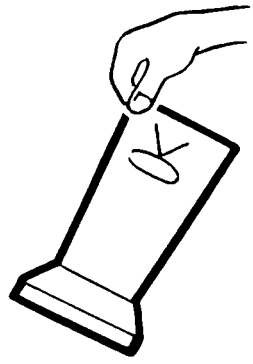
If I added a lead (or other heavy metal) sheet to the bottom of the base?



Edge-of-table method

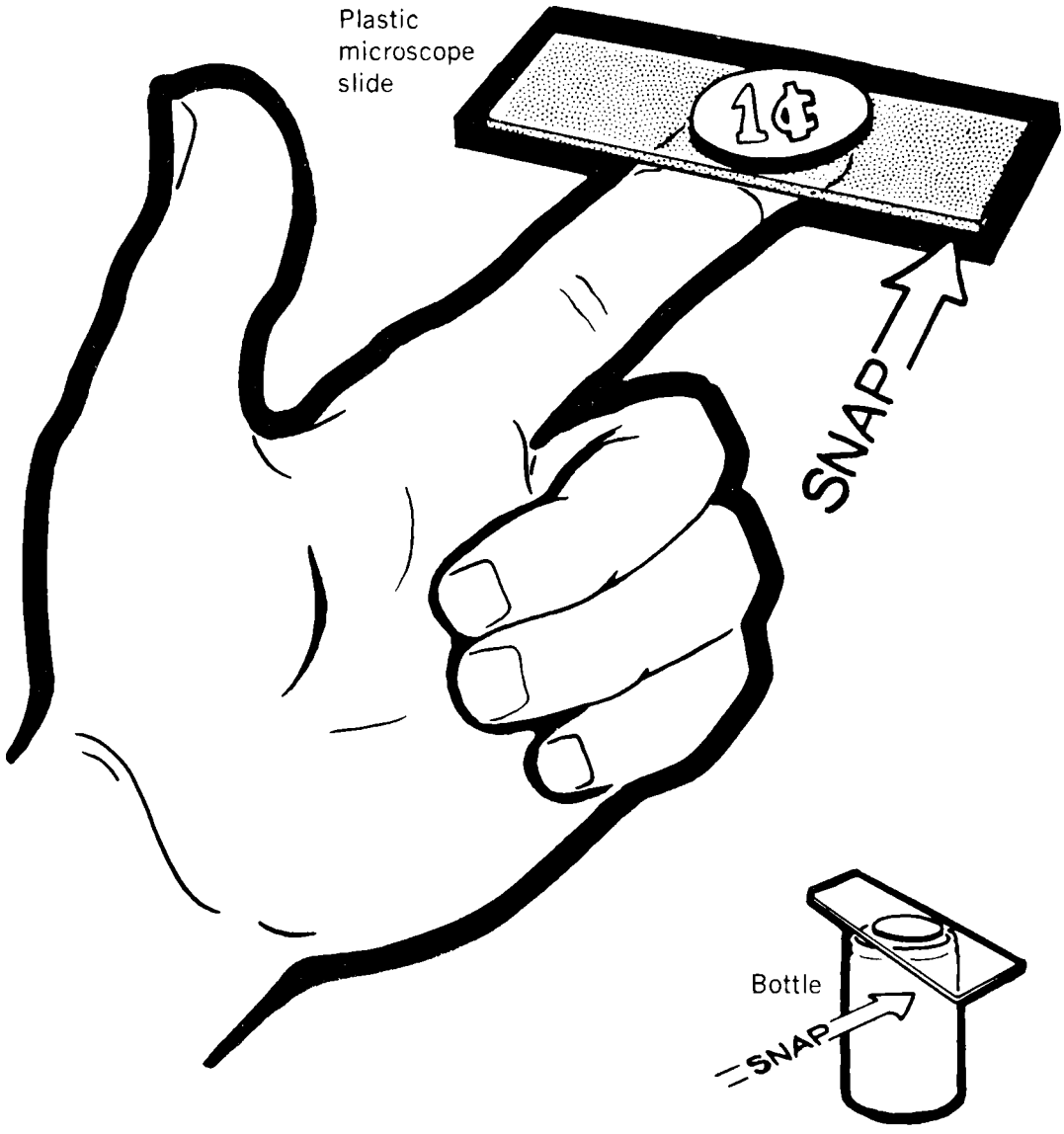


Balance-on-pencil method



Hanging method

Why does the penny stay on your finger when you snap the slide away?



the penny

If I used clay and changed the shape?

If lighter (and heavier) objects were used?

If I used a washer (feather, lead slug, bottle cap) in place of the penny?

If a drop of water (or oil) were substituted for the penny?

the slide

If I lubricated the slide?

Lighter	Heavier
Smoother	Rougher
Wetter	Drier

If a cardboard slide were substituted for the glass microscope slide?

Try a metal slide (or even sandpaper).

the snapper

If I snapped the slide slower (and faster)?

Jerk the slide away rather than snap it.

If I substituted a rubber band (or even a mouse trap) to snap the slide away?

the support

If I just picked up the slide with the penny and gradually accelerated it away faster and faster?

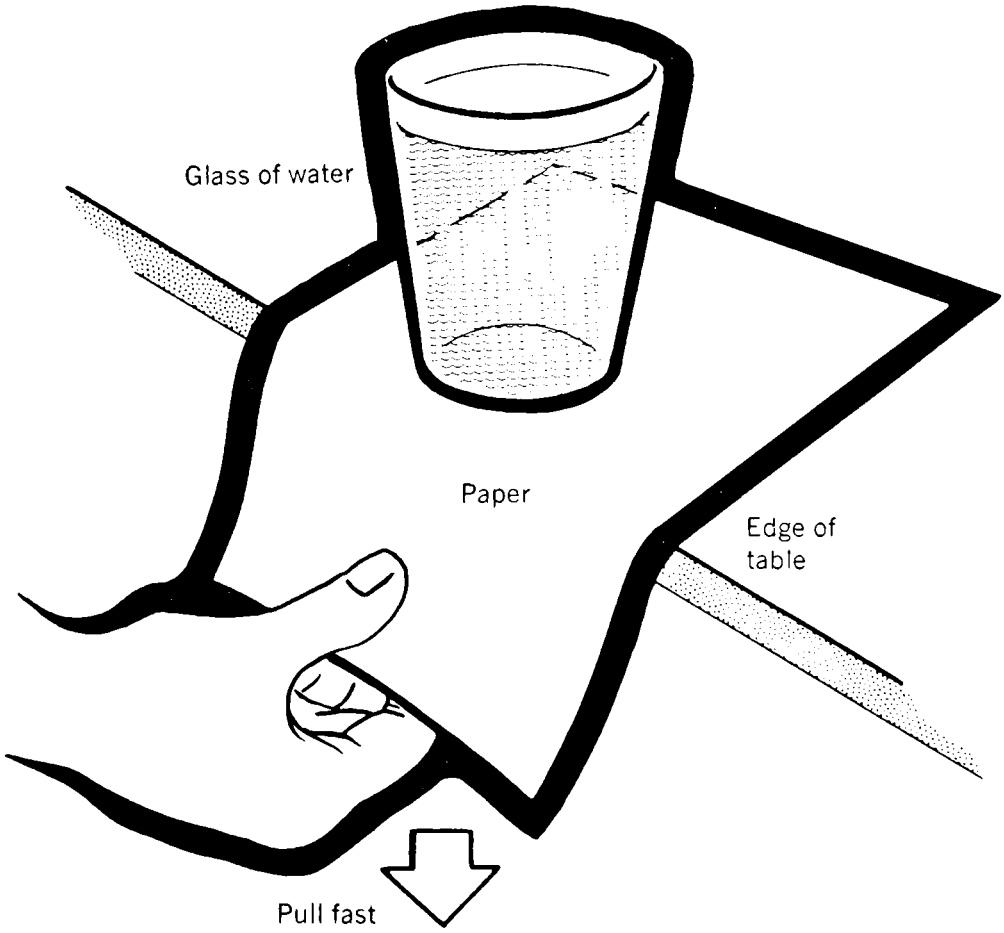
What is the critical speed at which the penny remains instead of moving away with the slide?

If I substituted a pop bottle for the support?

If a magnet were used for the support?

What were the most significant data which you discovered?

Why does the water not spill when you pull suddenly?



Put a dry glass of water on the paper, and pull it slowly to the very edge of the table. Suddenly jerk the paper down and away. Your glass of water will still be standing on the table. Why?

the water

If I used solid ice instead of the liquid water?

Try using hot water.

If I eliminated the water?

If the water were replaced with sand (or lead)?

the drinking glass

If I changed the shape in successive trials from tall and thin to short and wide?

If I did this underwater on the steps of a swimming pool?

If I used a box instead of the drinking glass?

If a baseball were used instead of the glass?

Also try a foam cup.

the hand that pulls

If I started slowly and then pulled fast?

Start fast and slow down.

If I used a mousetrap (or at least rubber bands) to pull?

the paper sheet

If I lubricated the paper?

Wet the paper.

Use waxed paper.

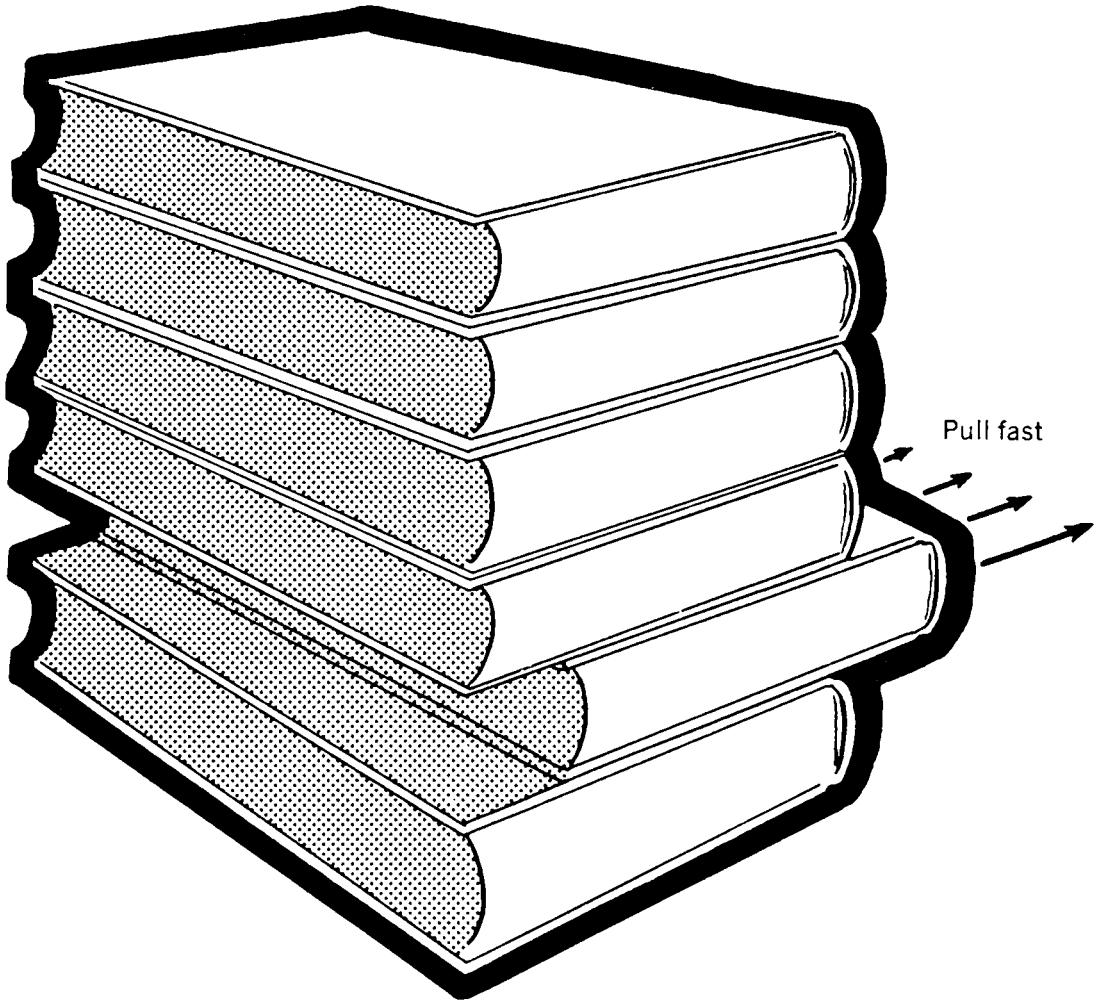
If I pushed a cardboard sheet instead of pulling it?

If I used a handkerchief instead of paper?

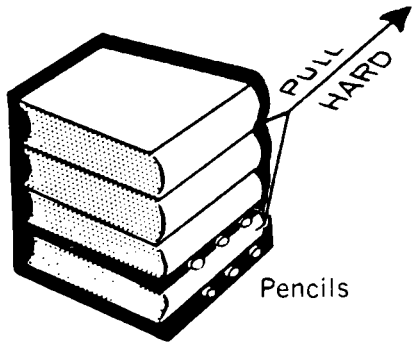
If I substituted sandpaper?

If stiff cardboard were used instead of flexible paper?

Why is it so easy to pull the lower book out without spilling the whole stack?



Haven't you often wanted the bottom book, bottom magazine, bottom box, bottom towel, or the bottom carton of cereal on the grocery-store shelf? A little practice and knowledge can help you get these very successfully.



If I put pencil rollers between the books?

Pull slowly, and then jerk suddenly.

If I put the books on the gym floor with a string tied to the bottom book and accelerated a walk gradually to a high-speed run?

If the book were pushed instead of pulled?

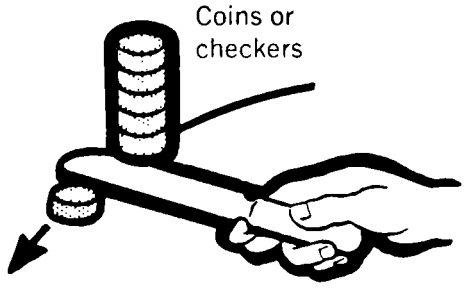
If I did this underwater using cement blocks?

If I used a taller (and shorter) stack?

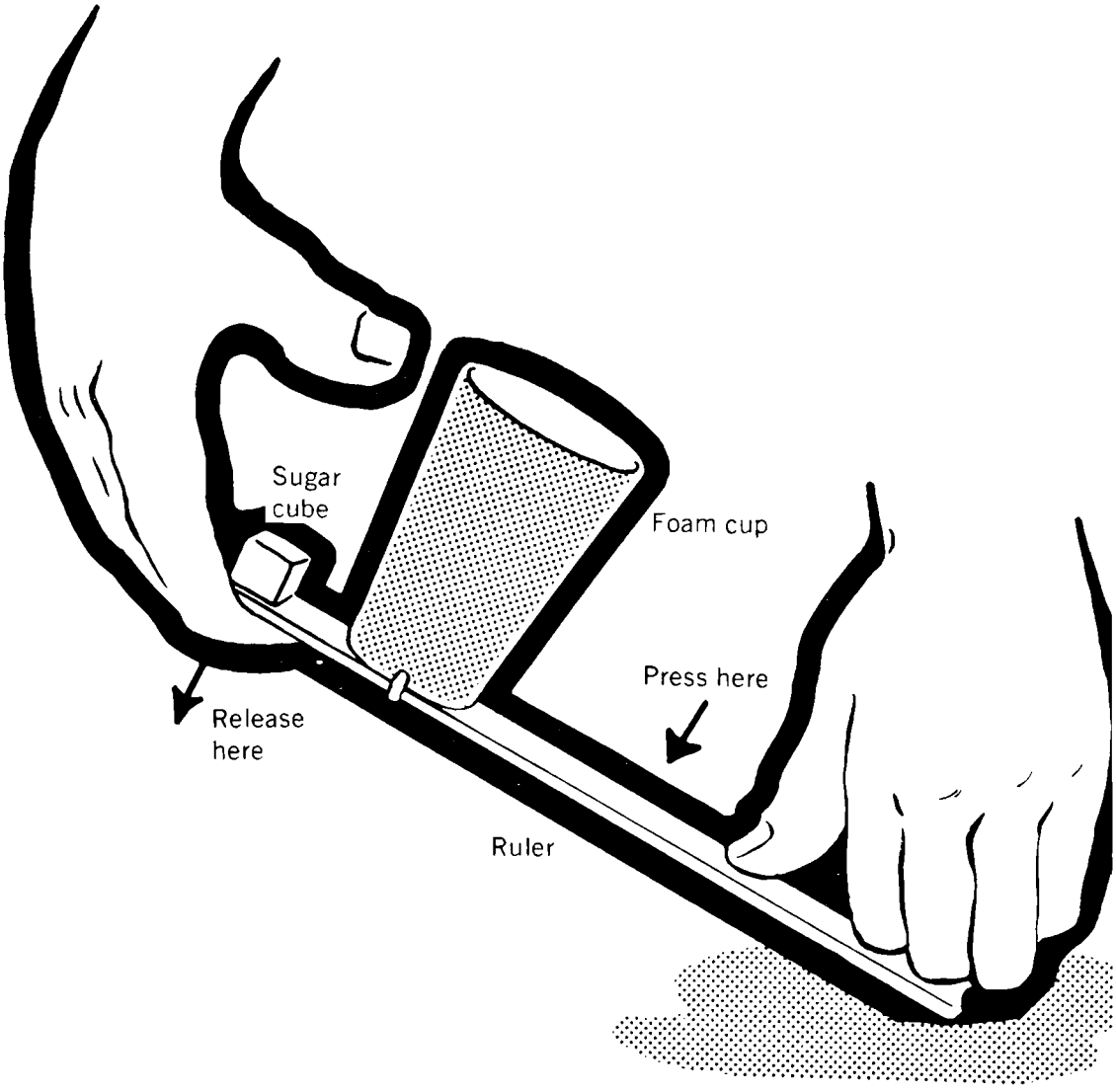
If heavier (and lighter) books were used?

If I changed the surfaces between the books with sandpaper (and waxed paper)?

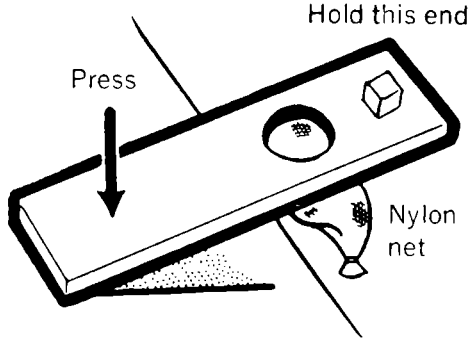
Use coins instead of books, and hit them with the dull edge of a knife.



Why does the sugar cube jump into the cup?



Tie the foam cup to the ruler with wire or string. Keep the sugar cube from sliding out of position with a small rubber band around the ruler. Press hard, and let go suddenly with the high hand.



If I cut a hole in a board instead of tying a foam cup to it and glued a nylon stocking net under it?

If I set up a vertical pencil marker in a clay base so that I could observe the flight of the cube better?

If the hand-held end were started higher (and lower)?

Press harder (and less hard) on the ruler.

If I substituted objects of different shapes?

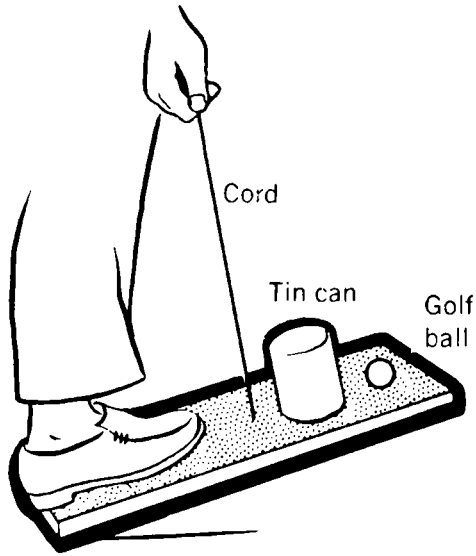
Substitute balls of different weights.

If the size only of balls were changed on successive trials?

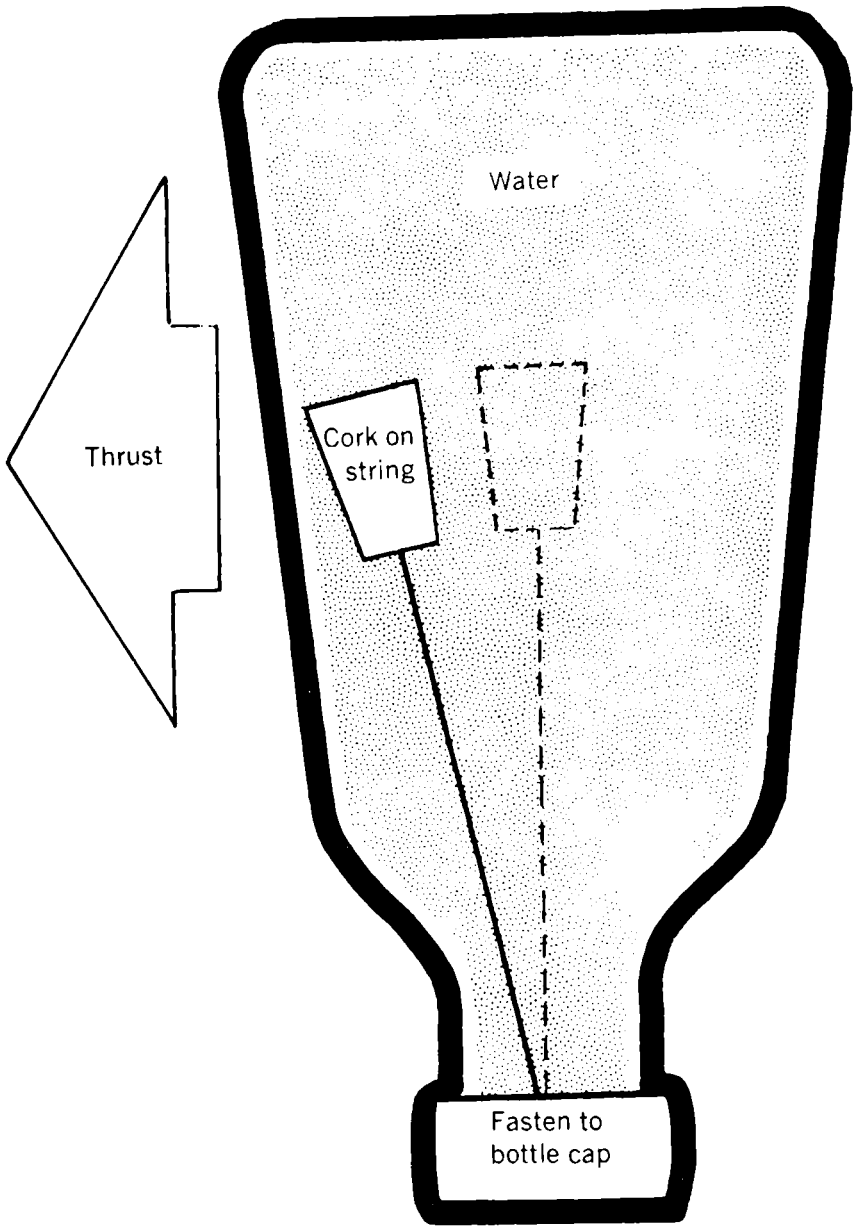
If I concentrated on the path of the falling ball?

If a yarn streamer were glued to the ball so its flight could be better observed?

If I made the equipment much larger in scale by using a big board, tin can, and golf ball?



Why does the cork go forward when the bottle is thrust forward?



Put the thread or string through the cork with a needle, and tie it through the liner of the bottle cap. If you put a pin hook through the liner, you can make changes faster in your experimenting.

the bottle

Hold the bottle out, and turn around and around.

If I varied the speed of the thrust?

If the bottle were taken in an automobile for a ride?

If I eliminated the bottle and tried the same event with a string and a cork in a swimming pool?

the water

Change the amount of water.

If little yarns were glued to the cork and inside the bottle to observe the water movements?

If I replaced the water with oil, salt water, or alcohol?

If I put bubbles in the water?

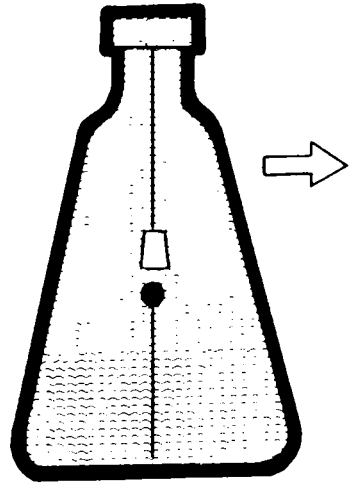
the string and cork

If I used a miniature balloon instead of a cork?

If a match (or a pencil) were used instead of a cork and string?

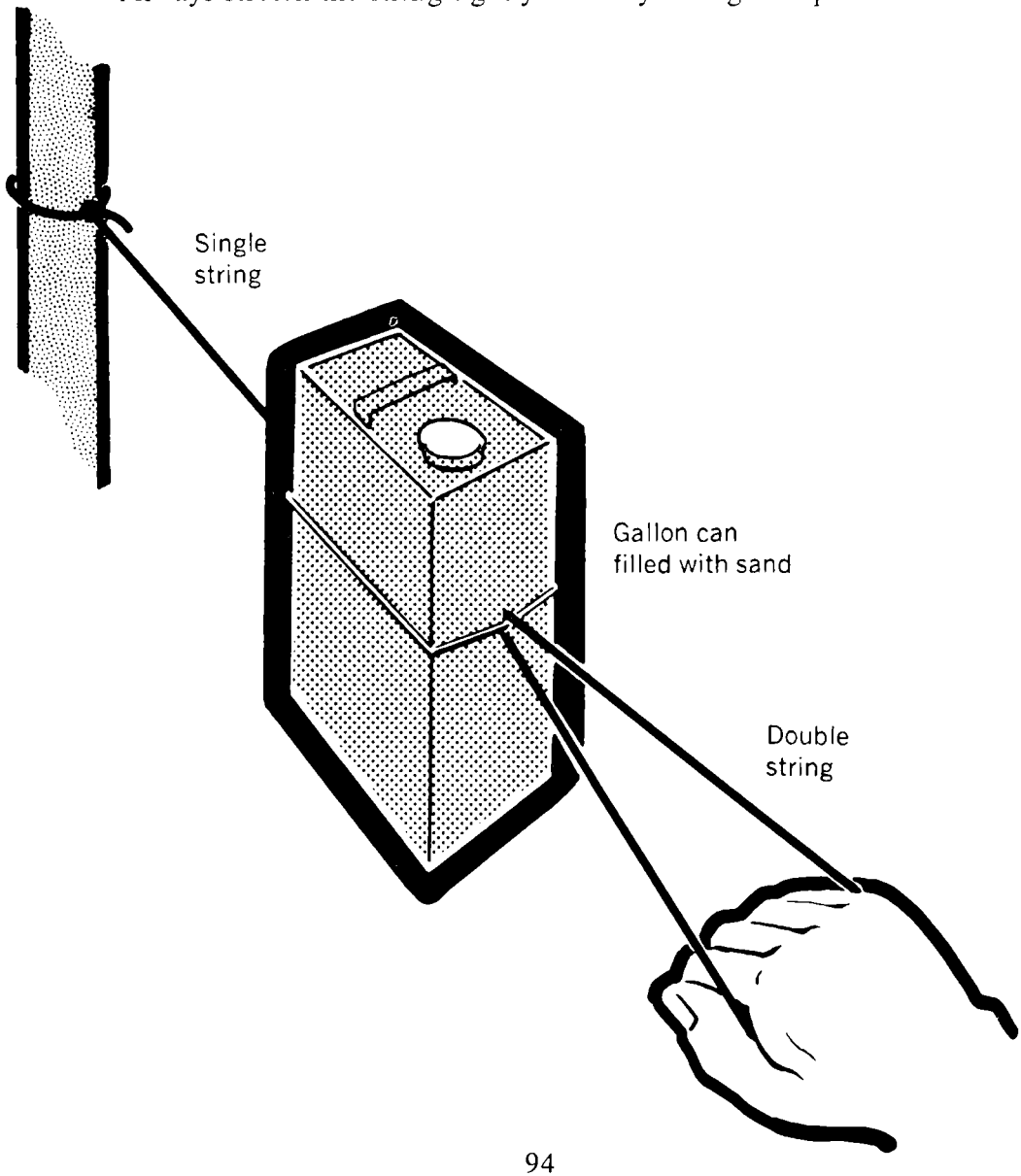
If I let the cork float without the string?

Put a floating and a hanging pendulum in the bottle of water at the same time.



Why does the double string break when you pull fast?

And why does the single string break when you pull slowly? Always stretch the string tightly before you begin to pull.



the heavy can

Vary the size of the weight.

If I anchored the weight and tried slow (and fast) pulls on it alone?

If a weight were dropped over a pulley instead of pulling it by hand?

If I substituted a can of water (dirt, nails, bolts, nuts, rocks)?

Try a bag of sand instead of the can.

If a stack of tightly tied books were used for the weight?

the strings

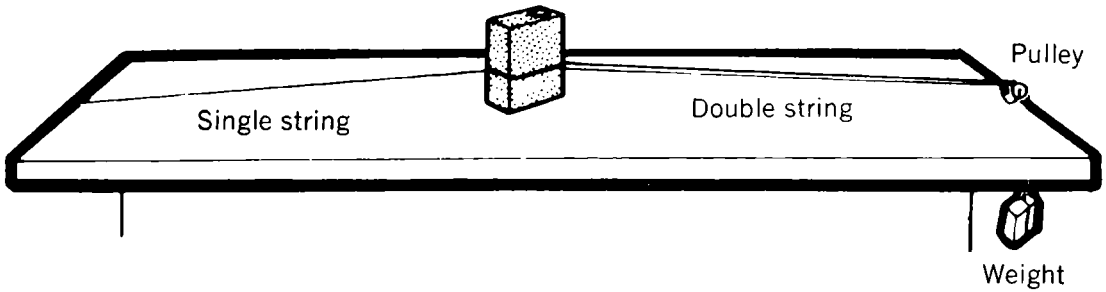
If I put a scale in line with the string so that I could measure the force?

Reverse the single for the double string.

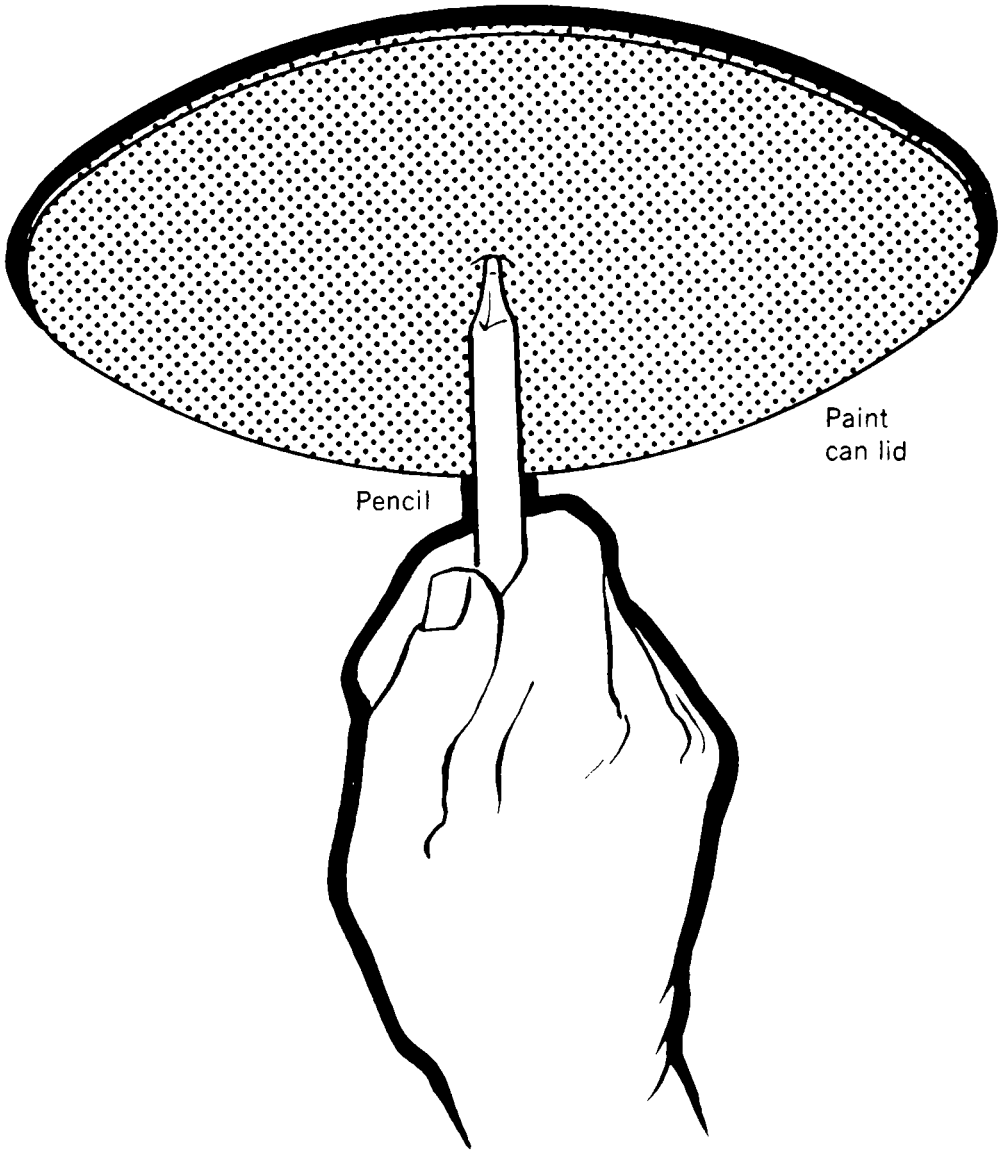
If I substituted thread, cord, fishing line, or wire?

If elastic bands were used?

If I tested my ideas on a tabletop like this?



Why is it so easy to balance a spinning disk on a pencil point?



If you cannot find an old paint-can lid, cut your spinning disk out of wood or fiberboard. Fiberboard is excellent because it does not damage things when it falls. Indent a small depression at the center of the lid with a dull nail. Also make a few off-center indentations on which to spin the lid while experimenting.

If I weighted the disk unevenly with clay?

Use a lighter (and heavier) disk.

If the shape of the disk (square, rectangle, triangle, free-form) were changed?

If I used a pie tin that hung low around the sides?

If I slowed the disk with friction during the event?

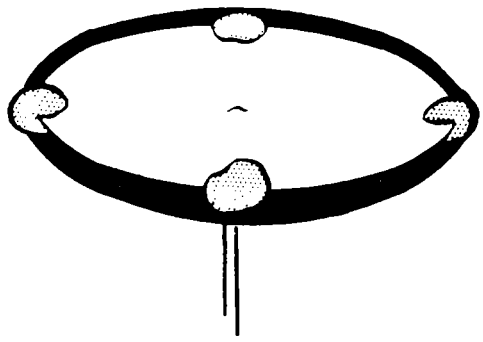
If I pressed hard on the spinning disk with a castor?

Spin the disk at an angle instead of level.

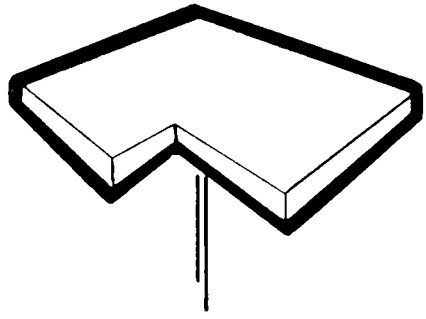
If a much longer and higher support were used?

If I tilted the support while the disk was spinning?

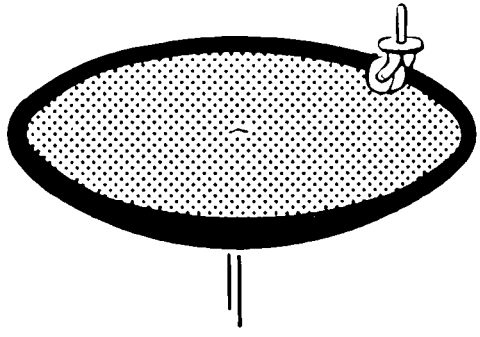
Did you keep control by changing only one factor at a time?



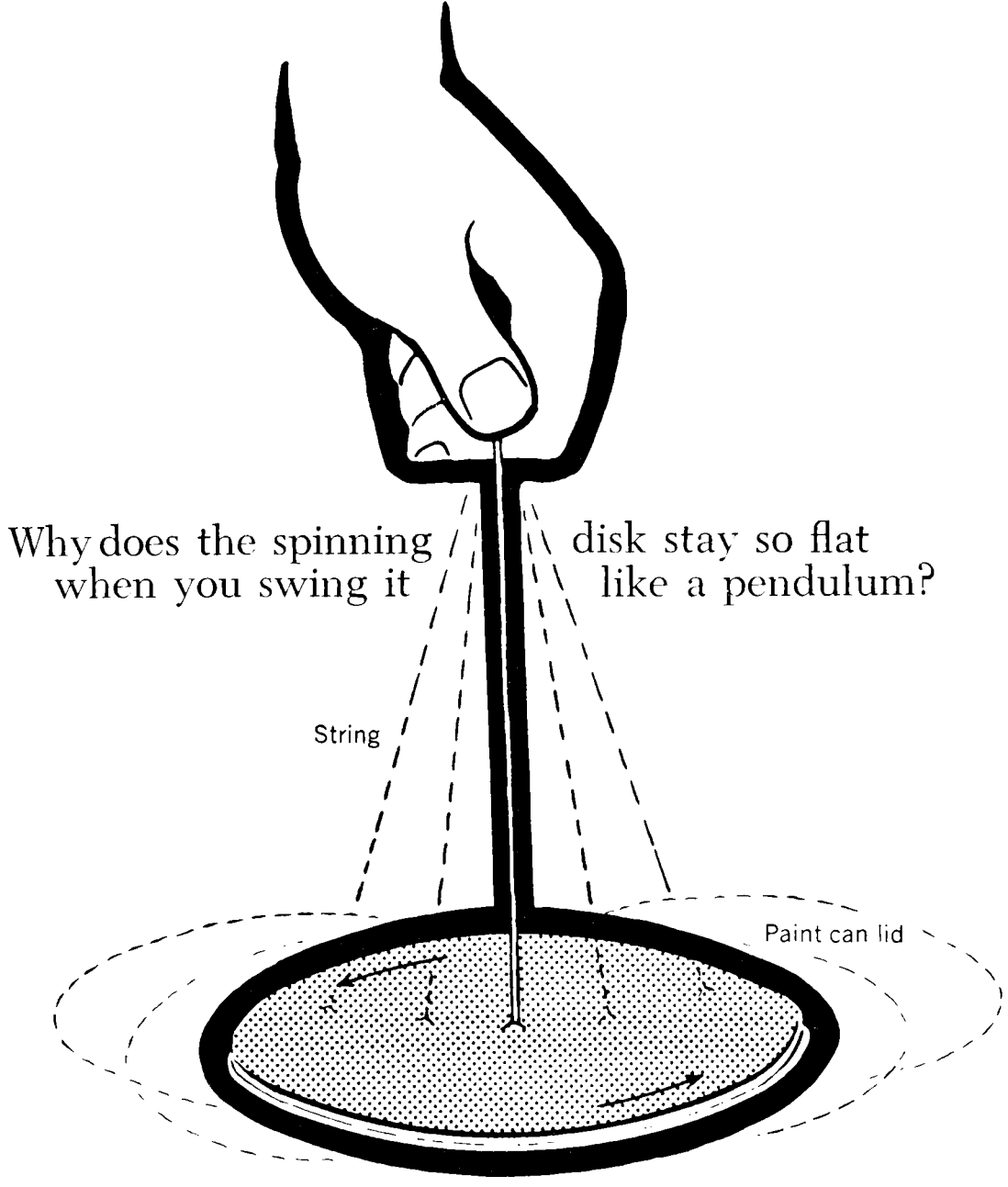
Change the weights



Change the shape

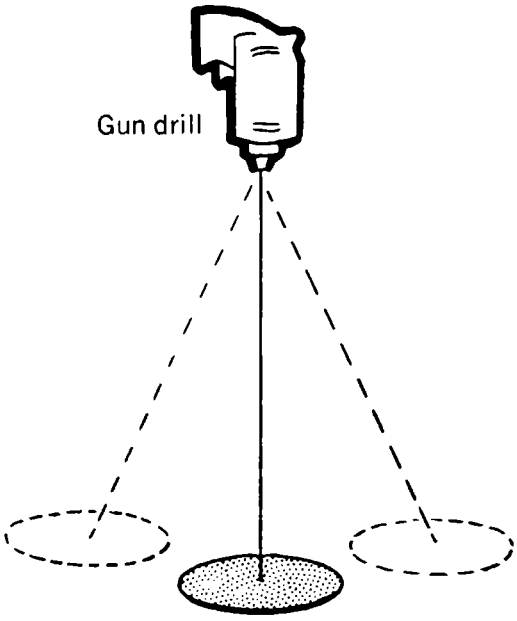


Change the pressure



Thread the string through a small clean hole in the paint-can lid, and tie a large knot. A fishing swivel can extend the life of the string tremendously. Drill several off-center holes with one even at the edge while you are drilling. If you have no drill, put the holes in from the bottom with a nail.

the spinning disk



Try spinning the disk with a gun drill.

If I used a foam disk instead of the paint-can lid?

If I made the weight uneven with balls of clay at the edge?

Change the direction of the spin.

If I pressed on the disk with a castor while it was spinning?

If the disk were lowered into water while it was spinning?

If I spun the disk at an angle instead of flat?

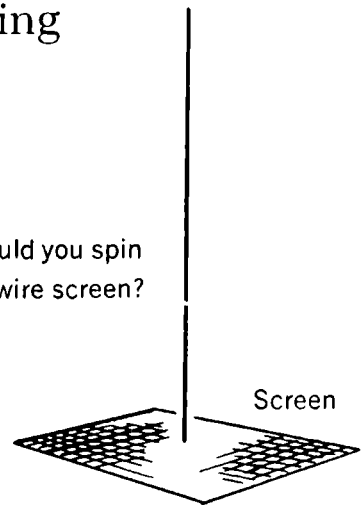
Could you spin a wire screen?

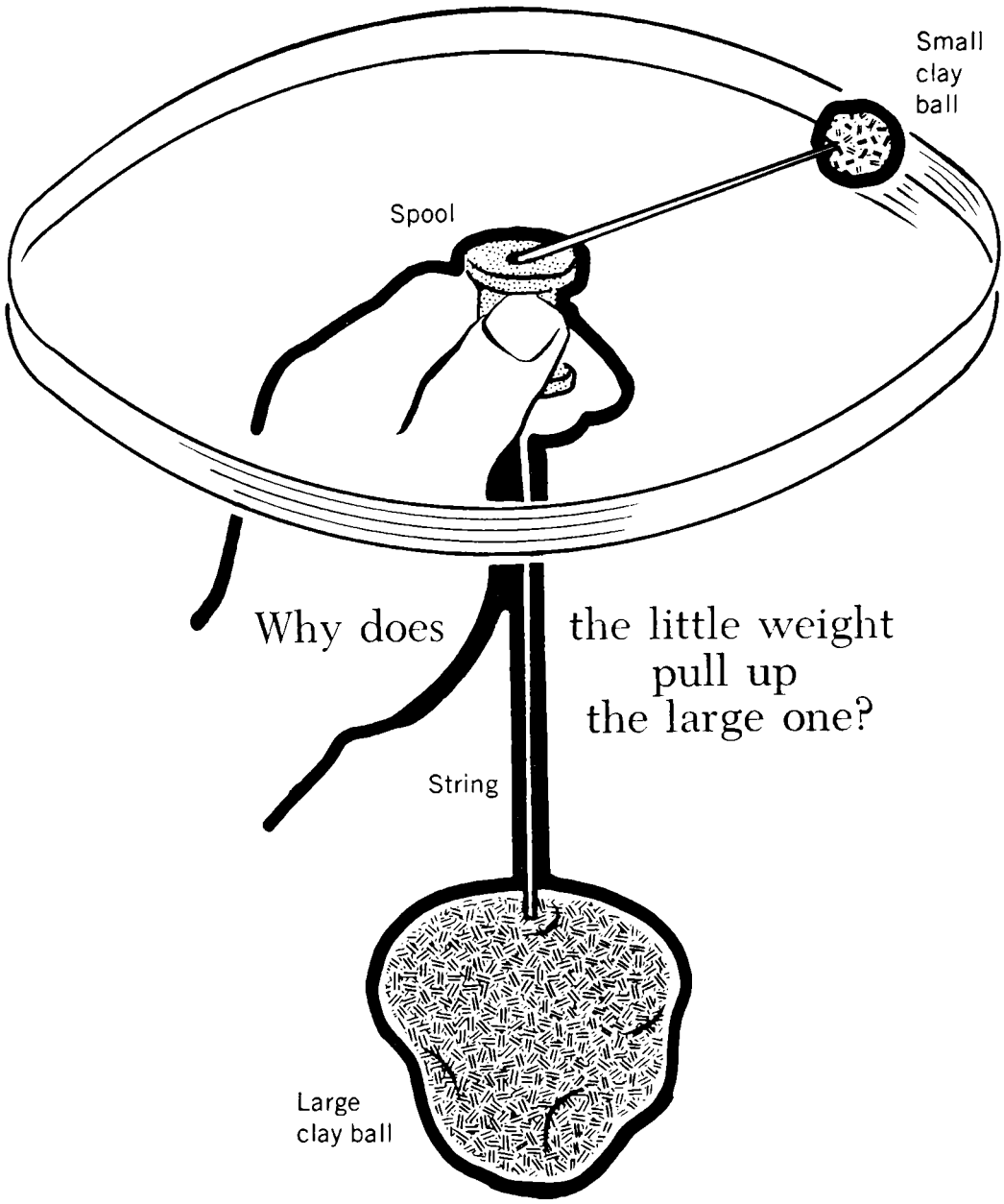
the supporting string

If I threaded the string through an off-center hole?

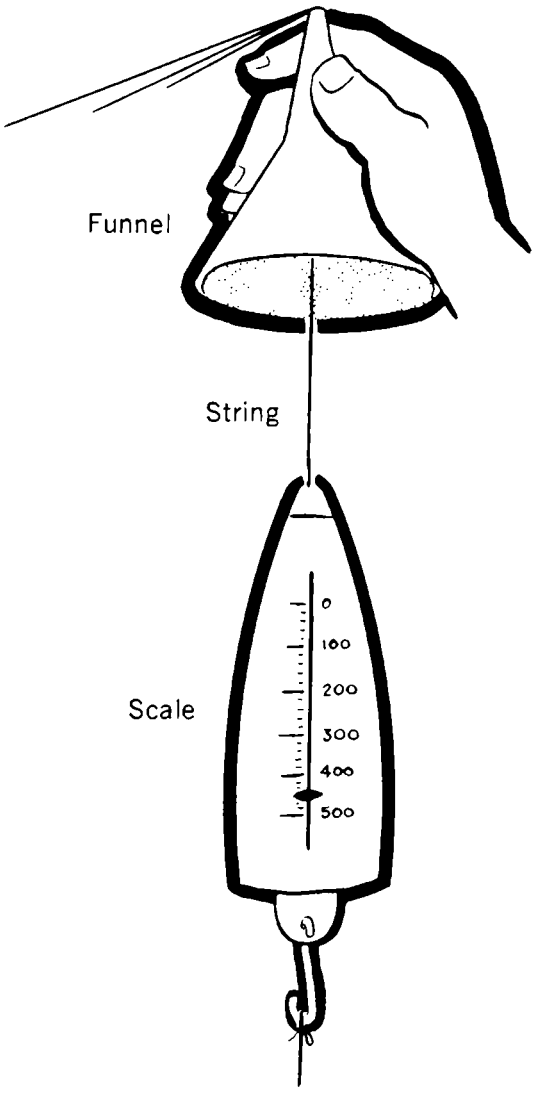
If the string were tied to the edge of the disk?

If I put a balloon full of water on the gun drill to spin and swung it back and forth like a pendulum?





Hold the spool, and swing the small clay weight around faster and faster. Rubber stoppers also make good safe weights.



Measure the upward force with a scale.

If I used a plastic funnel instead of a spool?

If heavier (and lighter) weights were used?

Swing the weights harder and harder.

If I held the bottom weight by hand and swung harder and harder?

If the spool was moved in a circle and then held steady in one spot?

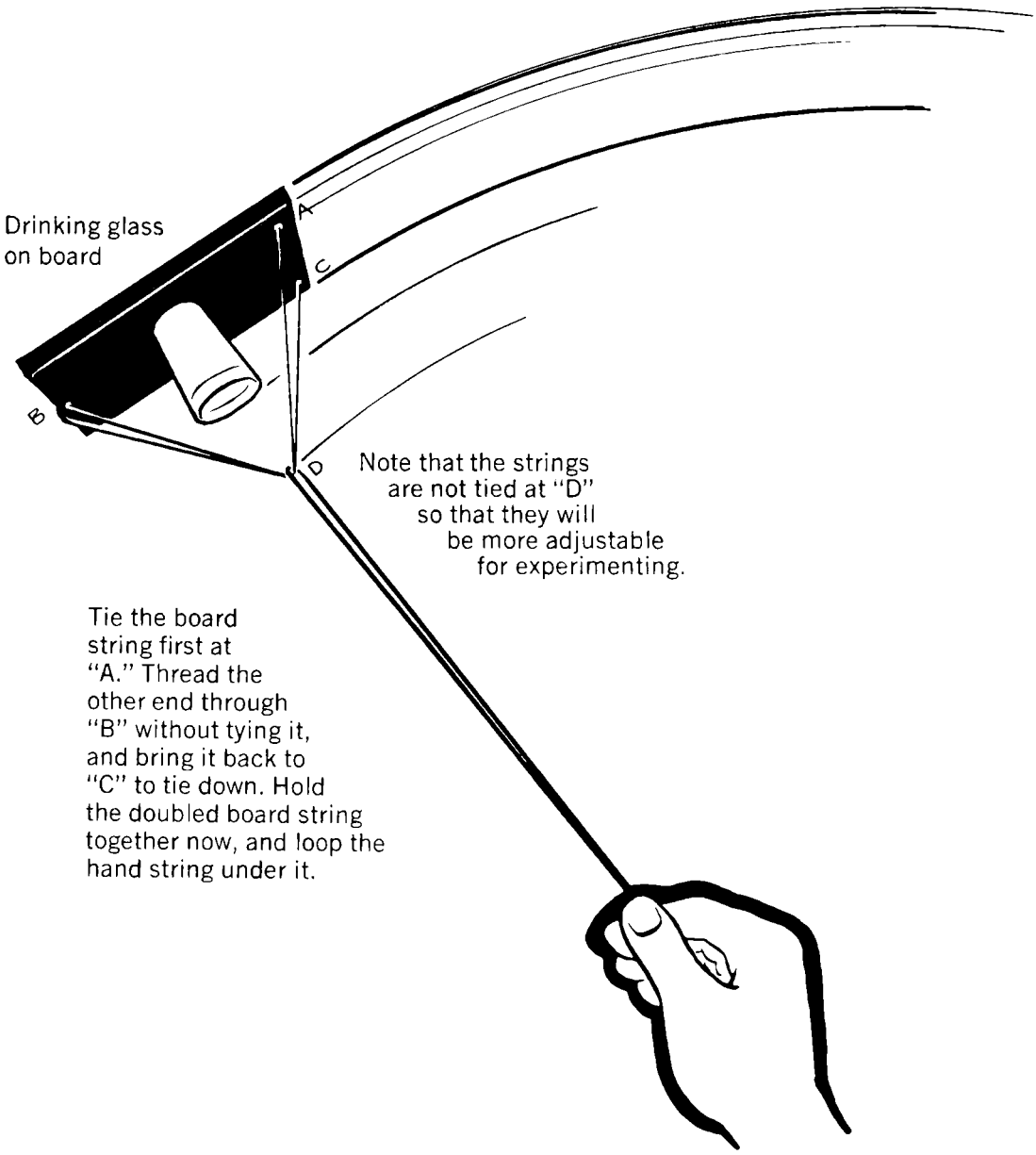
Use a longer (and a shorter) string.

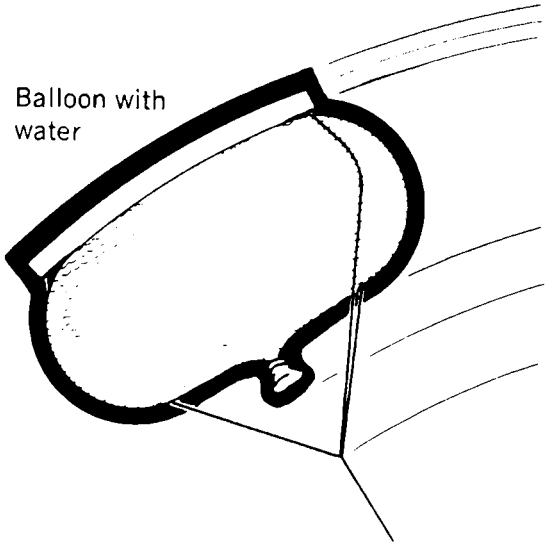
If I pulled the string down during the event?

If the string were let out longer and longer during the event?

If I inserted a scale in the string below (and above) the spool?

Why doesn't the water spill when it is upside down?


Drinking glass on board
A
C
B
D
Note that the strings are not tied at "D" so that they will be more adjustable for experimenting.
Tie the board string first at "A." Thread the other end through "B" without tying it, and bring it back to "C" to tie down. Hold the doubled board string together now, and loop the hand string under it.



the board

If I decreased the speed of the board until it was zero at the top of the swing?

If the size of the board were changed?

the string

If I used a rubber band instead of string on one side of the board so that it would tilt more and more with added centrifugal force?

Could you sink the ball with centrifugal force?

the liquid

If I substituted sand for the water?

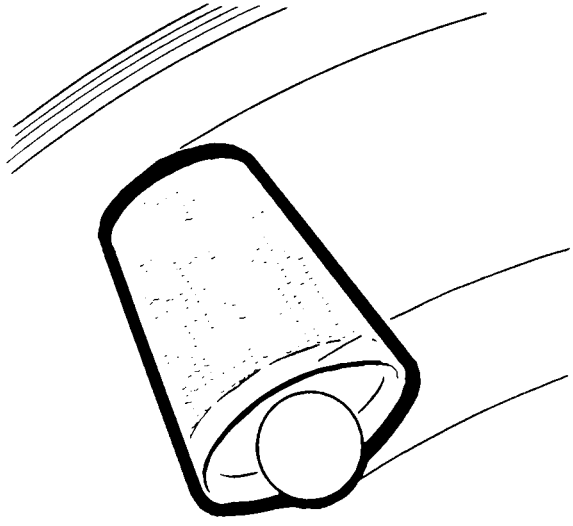
If I let the liquid leak through a hole in the side near the bottom of the tumbler?

the container

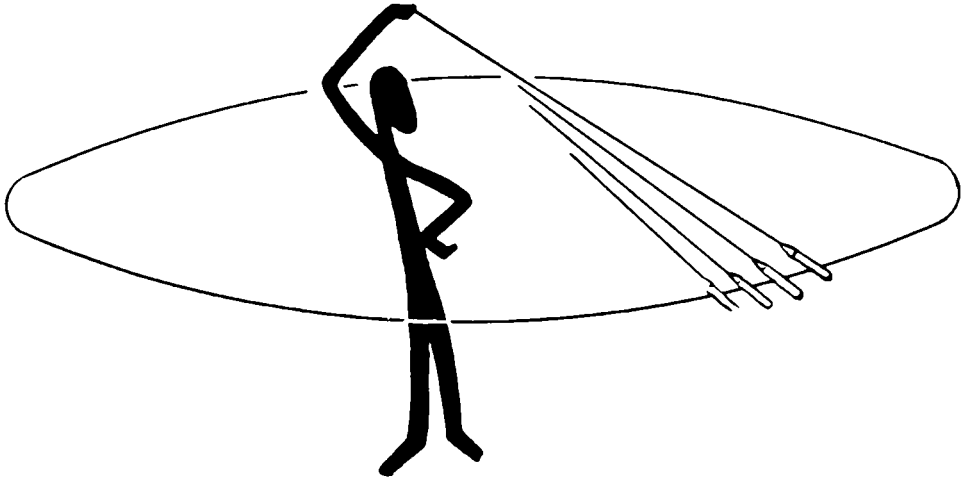
Use small and large containers.

If I used a flexible container like a balloon in place of the rigid glass container?

Which will break first, the balloon or the string?



How does my centrifuge work?



the string

What new data do you think that nature would offer if I substituted rubber bands for the string?

If I used wire in place of the string?

Try longer (and shorter) string.

If I used lighter (and heavier) string?

If a scale were inserted in line with the string?

the centrifuge tube

If I substituted a balloon filled with water for the tube?

Use lighter (and heavier) tubes.

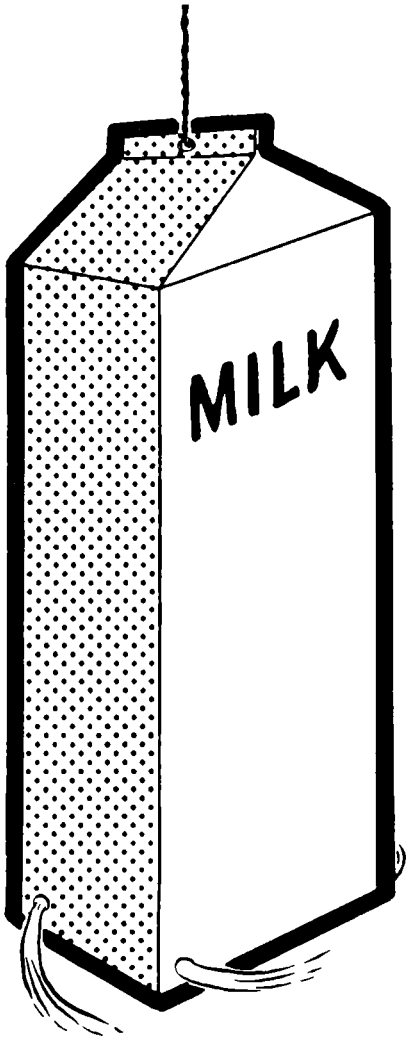
If longer (and shorter) tubes were tried?

the power hand

If I substituted a gun drill for the hand power?

If the tube were whirled slower (and faster)?

Why does the milk carton spin?



Put a one-quart milk carton inside a larger two-quart carton of water to fill it.

Put a pie tin under the milk carton to catch the spill.

the milk carton

If I put four holes in line vertically on one side instead of a hole on each of the four sides?

Make smaller (and larger) holes.

If the holes were higher on the sides of the carton?

If I put the holes in the middle of each side?

If I extended the holes with straws or tubes?

the water

If I substituted salt water (or oil)?

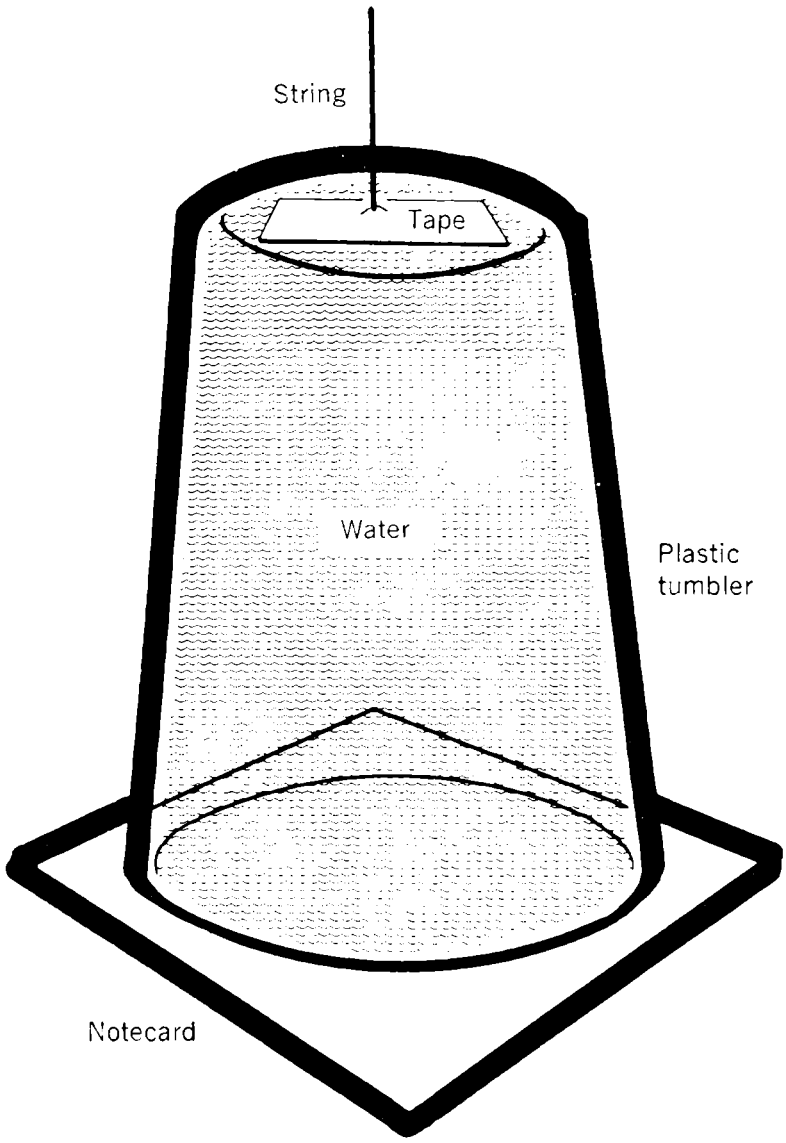
Use less (and more) water to start the event.

If water were added with a hose during the event?

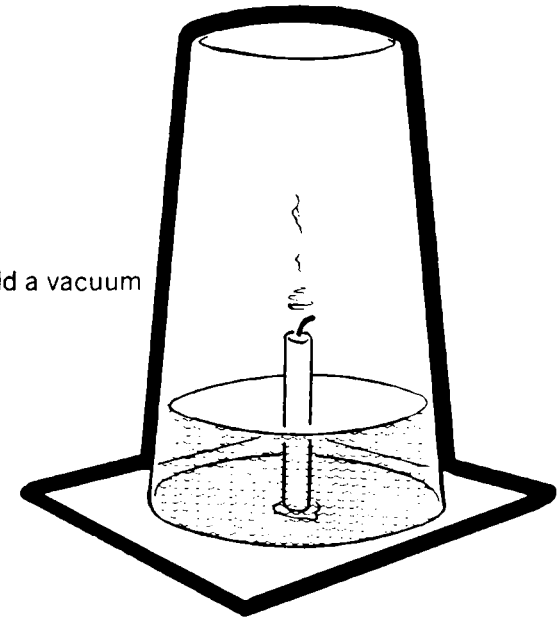
If I sealed the top just before I started spinning the carton?

Can you think of other variables to change?

Why does the water not spill out of the inverted tumbler?



Fill the tumbler until it overflows. Cover it with a note card. Press gently on the center of this note card cover, and let it spring back to its flat shape. Put your hand over the cover, and invert the tumbler of water. Hold it in your hand, or suspend it on a string.



the liquid

If I eliminated the water and just wet the cover?

If the event were repeated underwater instead of in the ocean of air?

Change the amount of water.

If I stuck a candle to the cover, put it underwater, lit the candle, and covered it with the tumbler as shown above left?

the container

If I turned the container sideways instead of upside down?

Tape the container to a cord and swing it around and around.

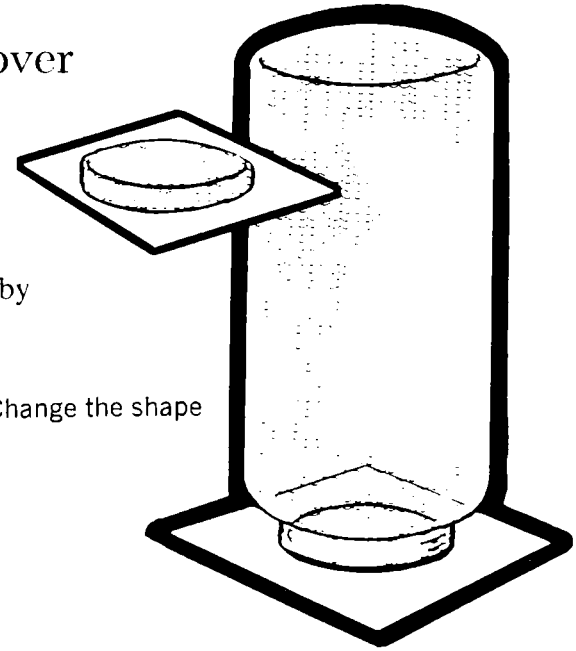
If I shook the container up and down?

the cover

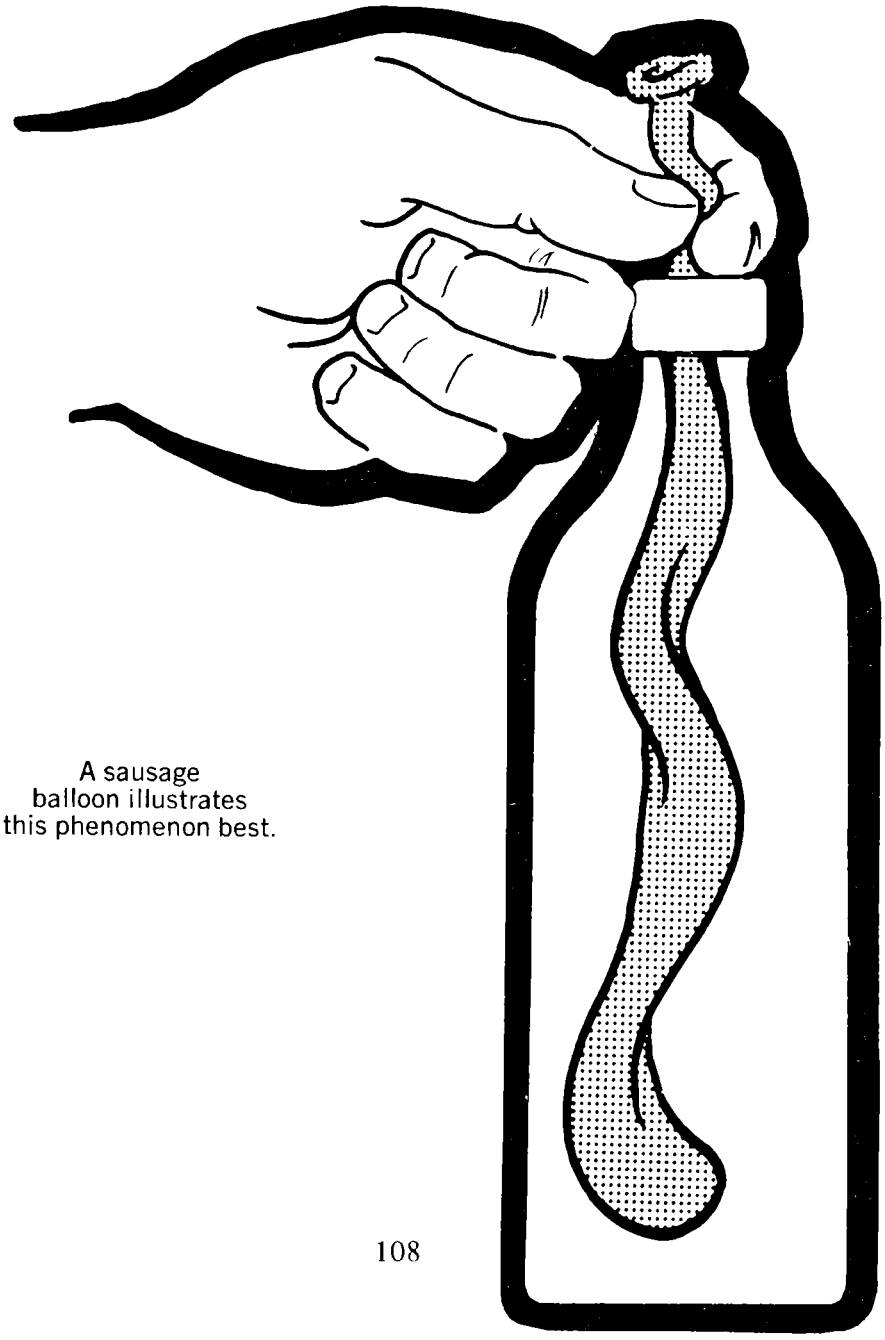
If I substituted a tin-can-lid cover?

Try a corrugated cardboard cover.

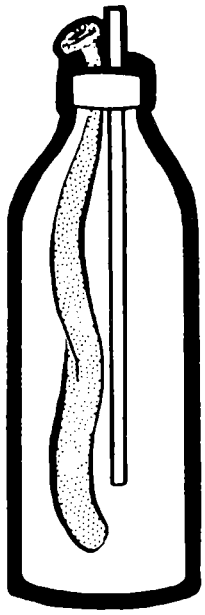
If the air pressure were eliminated by doing the event in a vacuum chamber?



Why can you not blow up a balloon in a bottle?



A sausage balloon illustrates this phenomenon best.



Add a soda straw

the balloon

If I used smaller (and larger) balloons?

If the balloon were filled with water instead of with air?

If I placed a drinking straw beside the balloon in the bottle?

Remember to keep all factors under control as you manipulate just one variable at a time.

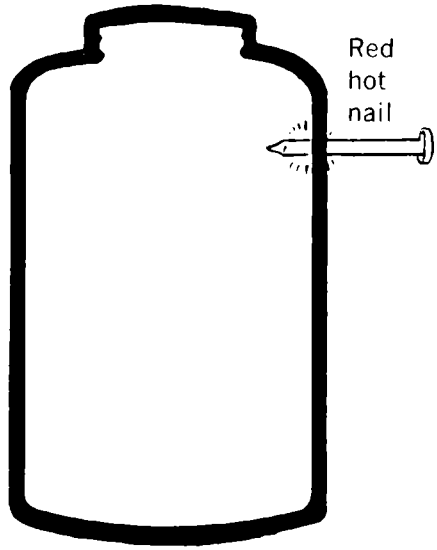
the bottle

Change the shape.

Change the size.

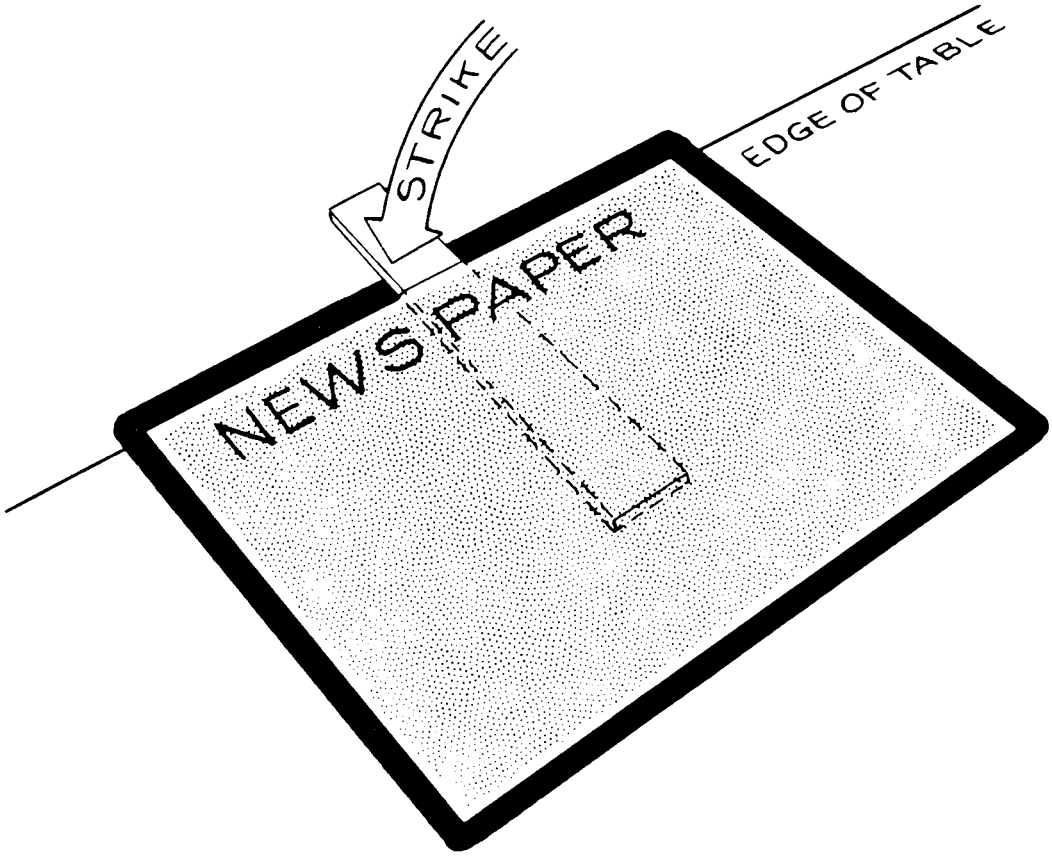
If I used a plastic bottle and melted a hole through it with a hot nail?

If I plugged the hole and then unplugged it after the balloon had been blown up as far as possible?

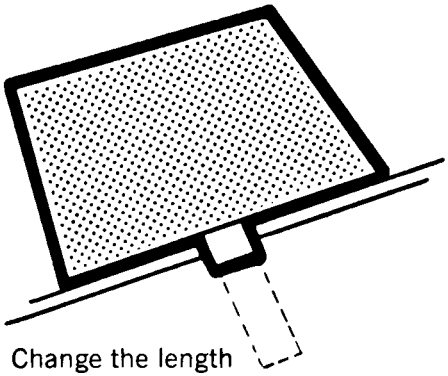


Melt a hole in a plastic bottle

Does air pressure really break the board when you strike?



The boards which are usually used for this experimenting are the slats from vegetable crates which are thrown out at markets each day. Ask your grocer to save them for you.



Change the length of the lever

the board

If I changed the distance that the board was sticking out of the paper?

Try wider (and narrower) boards.

If thicker (and thinner) boards were used?

Set the board on edge.

If I changed the placement of the board under the paper?

If I placed the board at an angle?

the striker

If I substituted a hammer (or a ball bat) for the fist?

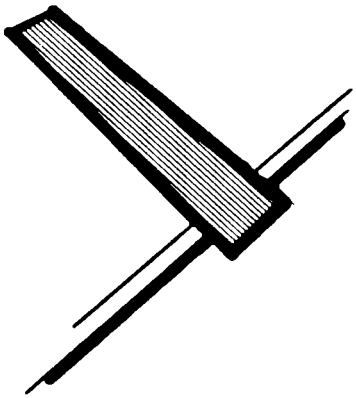
Try a judo cut for the strike.

the newspaper

If I wet the newspaper?

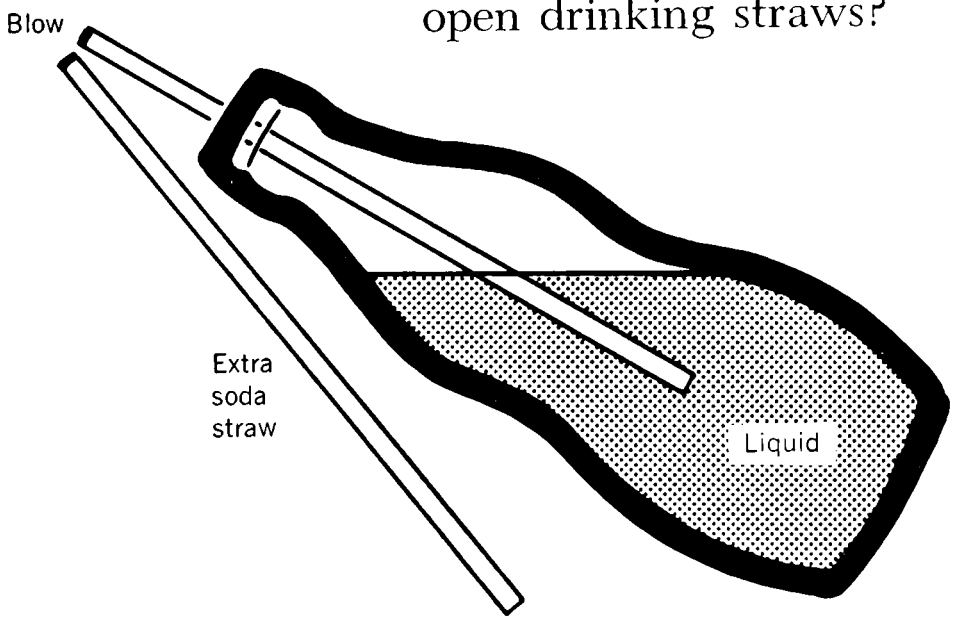
Crumple the paper.

Change the size. How about covering a toothpick with a postage stamp?



Eliminate the paper

Why is it impossible to drink through two open drinking straws?



the straws

If I put a finger on the end of the outside straw?
If the end of the outside straw were gradually pinched tighter?
Use longer (and shorter) straws.
If the straws were narrower (and wider)?

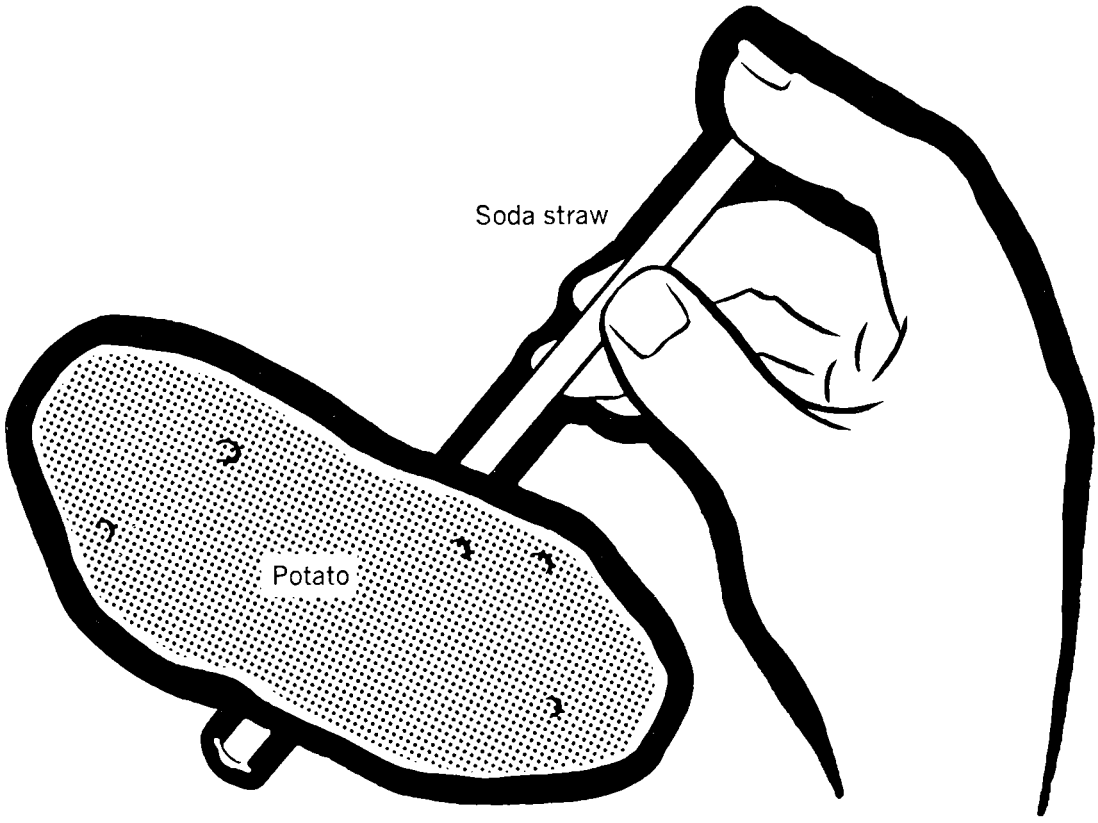
the bottle

If I used an open cup rather than the bottle?
If the bottle were plugged with clay around the straw?

the liquid

If I fastened a vacuum syringe to the straw?
Try more (and less) liquid.

How can some people punch a soda straw through a potato?



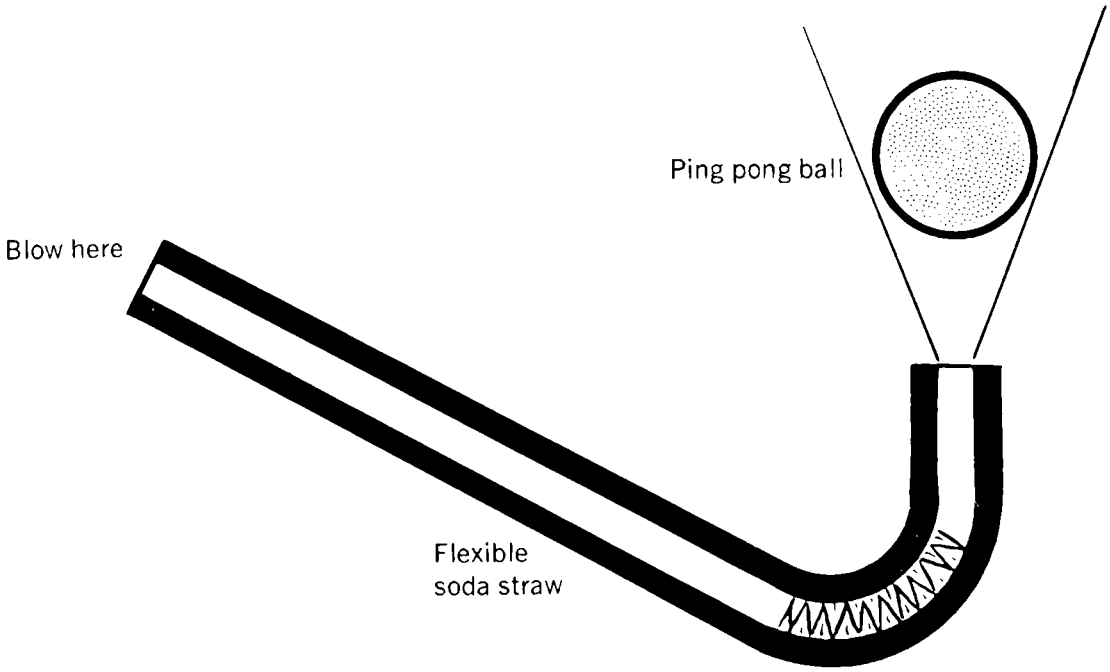
the potato

Try several kinds of potatoes.
If I substituted apples, oranges, or bananas?
If I peeled the potato?
Try a baked potato.
If the potato were hit at a slant?
If I repeated the event underwater?

the straw

If I struck the potato slowly (and fast)?
If I did not put a finger on the end of the straw?
Seal the end of the straw to hold the air.
If the straw were filled with water?
If I put small pinholes in the straw?

Can you balance a Ping-Pong ball over a soda straw?



Use a flexible straw or tubing. Blow by mouth, vacuum cleaner, paint sprayer, or anything which will blow steadily. Do not let go of your ball until the airstream is blowing steadily.

the straw

If I substituted a rubber or a plastic tube for the straw?

If the tube were metal (or glass)?

Try it without a tube.

Try larger (and smaller) tubes.

If I tried this in a swimming pool with a high-pressure hose and a heavier-than-water ball?

the ball

If I tried a balloon (foam ball, tennis ball, marble, or BB) in place of the Ping-Pong ball?

Try a foam cube instead of a ball.

If I changed the shape of the ball by denting it?

If the ball were balanced on the straw before the blowing began?

Try a lighter (and a heavier) ball.

the blower

If I substituted a vacuum cleaner blower (or a paint sprayer)?

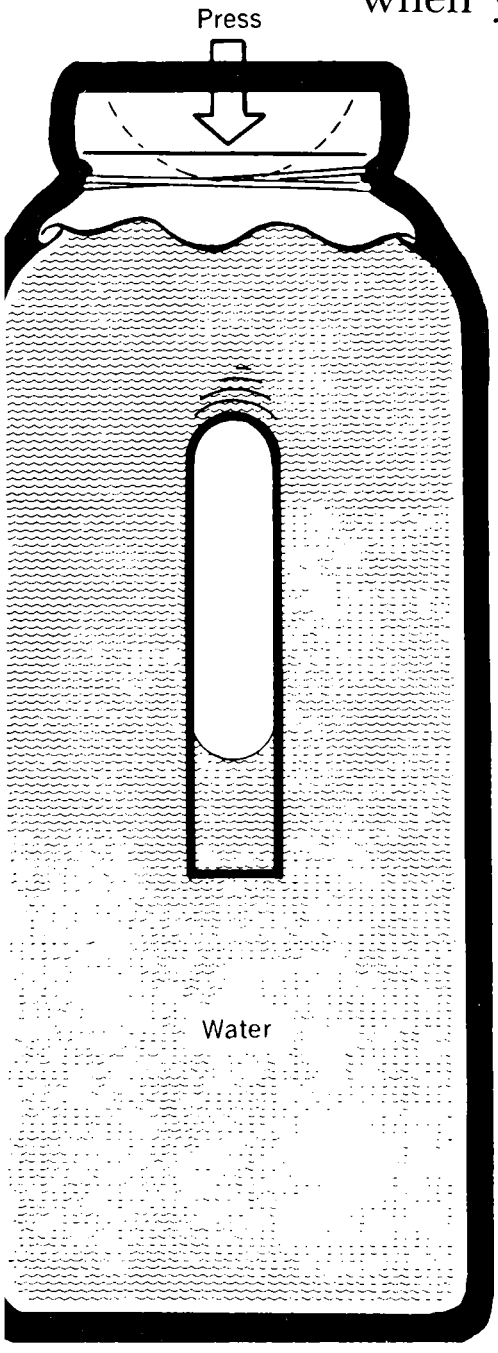
Be sure to get fittings such as tape and tubes, or at least a funnel, to be able to change the airstream.

If I blew softer (and harder)?

If the blower were tipped to the side?

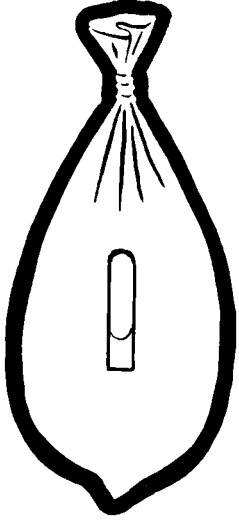
If I moved the blower up and down while the ball was balanced?

Why does the diving bottle go down when you press?



Use a medicine dropper if you cannot find a small vial or test tube for a diver. With a very large bottle you can use a small bottle for the diver. The sheet used to cover the top of the bottle may be cut from a rubber balloon.

Adjust the diver until it barely floats in a wide-mouth container. Put your finger over the open end, and transfer it to the jar. Or you can use a tube with a hooked end to adjust the amount of air in the diver until it barely floats. A medicine dropper is easiest to adjust, but harder to observe for data.



the container

If I changed the shape of the container?

If a plastic sheet were used for a cover instead of the rubber?

Use a milk bottle, and press with the heel of the hand instead of pressing on the sheet.

If I corked the bottle and pressed the cork in and out?

Try a rectangular sealed bottle and press the sides in instead of pressing on the top.

the diver

If I used a match head in a small bottle instead of a medicine dropper or small vial?

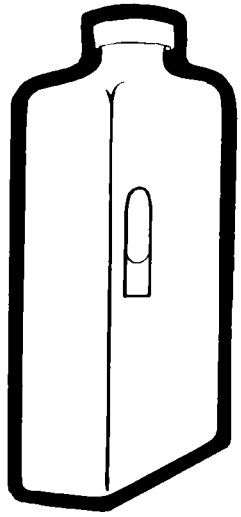
the liquid

If I used a flexible plastic bag in place of the rigid glass?

If I substituted a viscous oil (or molasses) for the running water?

Change the amount of liquid.

If I tried to add centrifugal force by turning around and around?

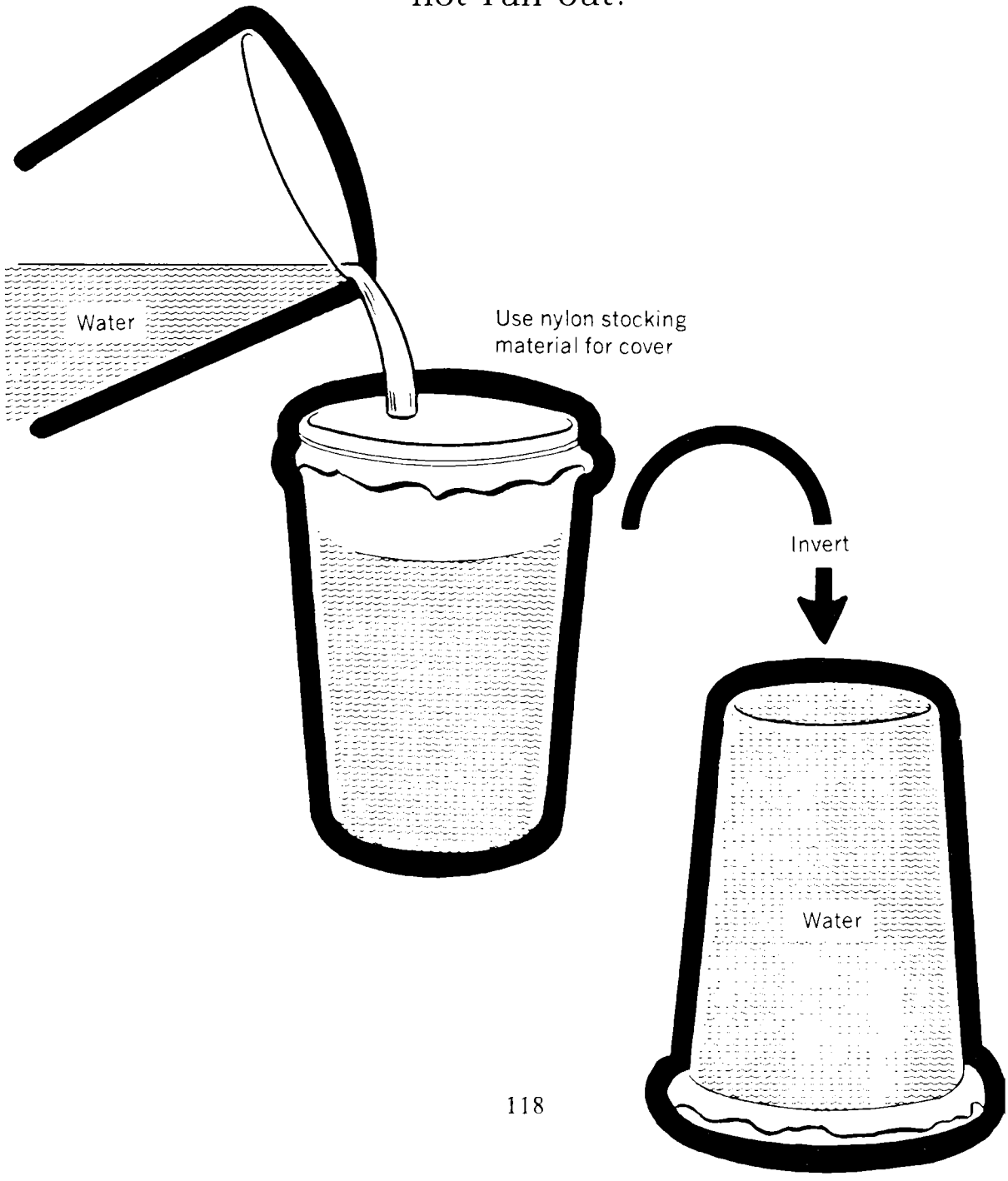


Try a sponge.

If the diver were adjusted to float higher (and lower) before starting?

If I inverted the whole system and tried again?

The water runs in, but why does it not run out?



the container

If I tried a plastic bag and made a stiff neck by putting it inside a pet-food can with both ends cut out?
Try a plastic tumbler instead of glass.
Change the shape of the container.
If the size were changed from that of a thimble to that of a gallon jar?
Put a hole in the bottom.

the nylon-stocking cover

If I tried gauze and other kinds of cloth?
Change to plastic (and metal) screens for a cover.

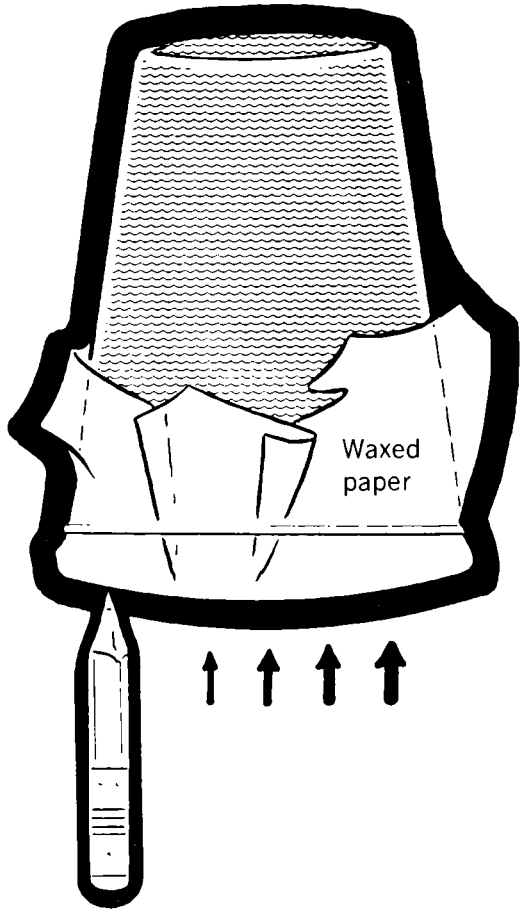
the water

Eliminate the water.

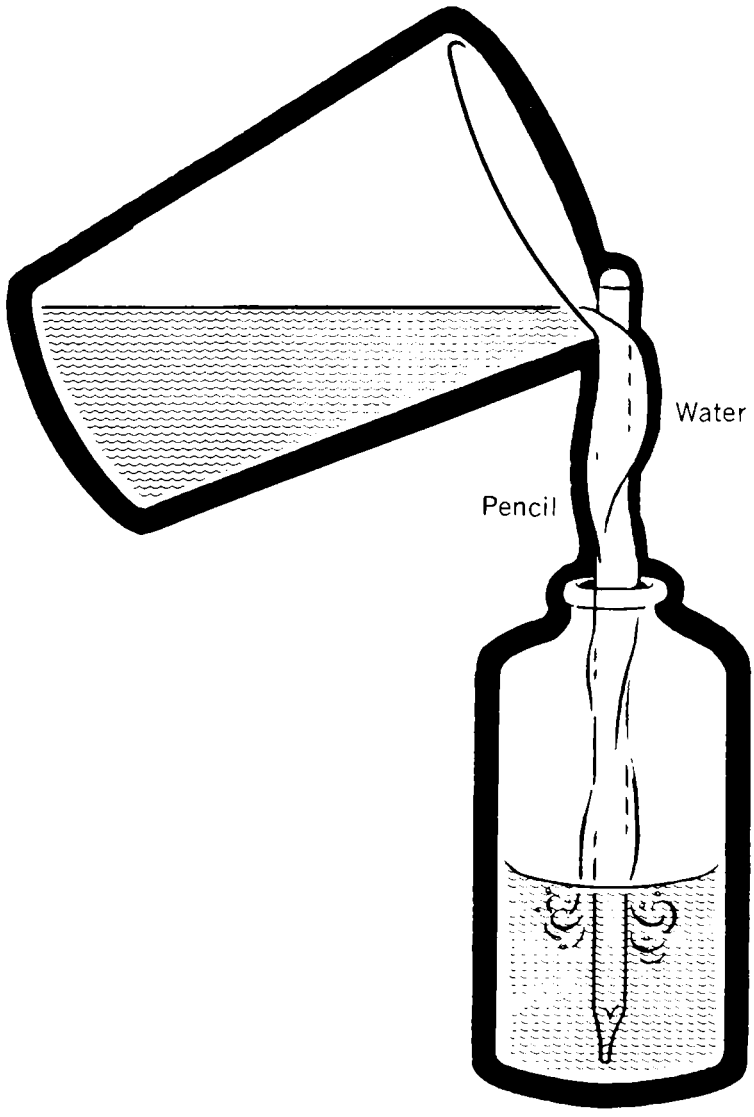
If I tried alcohol (salt water, molasses, milk)?

If sand (or at least a powder) were used in place of the liquid?

If I punched larger and larger holes in nylon, waxed paper, and aluminum-foil covers?



Why does water run down the pencil so well?



the water

If I substituted milk (salt water, oil or syrup)?
If I poured sand (or a powder)?
If I added detergent to the water?
If I dissolved various things into the water?
If I poured more (and less) water per minute?
Pour hot (and cold) water.

the pencil

Substitute a chain for the pencil.

If a band of cloth were tried in place of the pencil?

If I waxed the pencil with a candle?

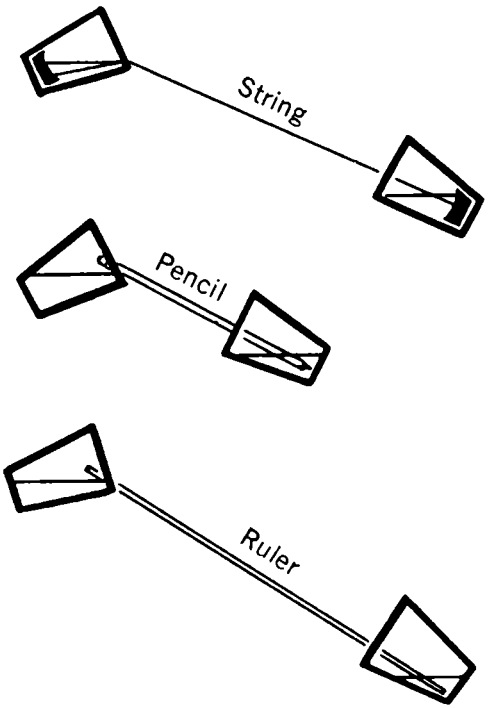
Replace the pencil with a string.

If a glass (metal, wooden, or rubber) tube were substituted?

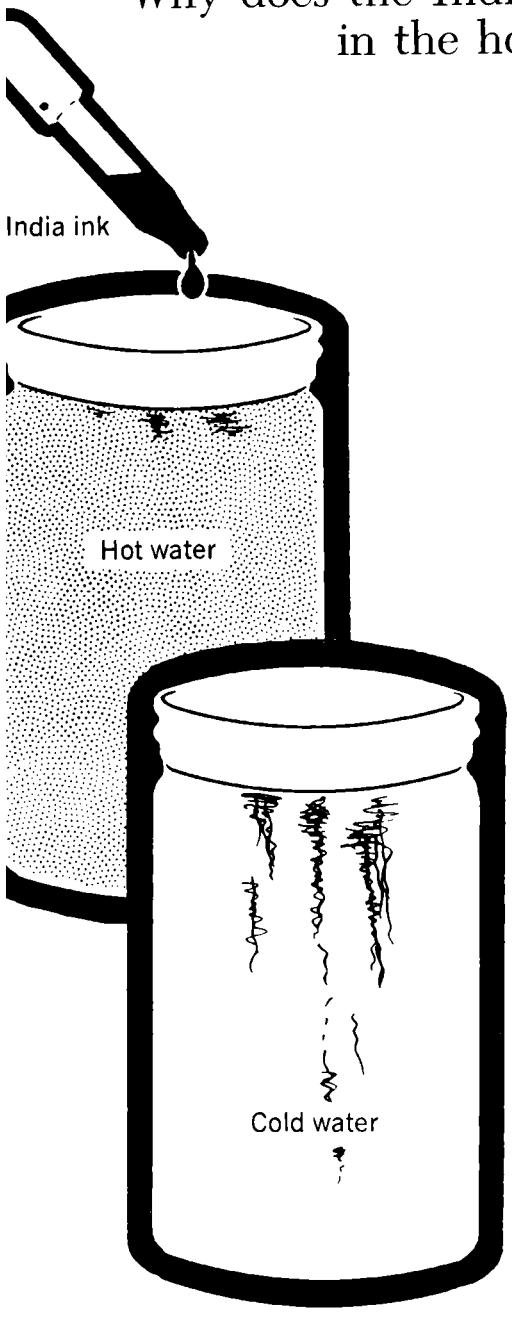
If I tried to pour down through a drinking glass held horizontally and broadside to the falling water?

Try to pour down an irregular shape like that of a large serving spoon.

If I tried to pour water down slanted objects?



Why does the India ink spread faster in the hot water?



If I substituted cooking oil (vinegar, milk, salt water, molasses, or a cardboard drink)?

Add detergent to the water.

If charcoal or briquet dust were used in place of the India ink?

If the ink were warmed before the event?

Substitute vegetable dye.

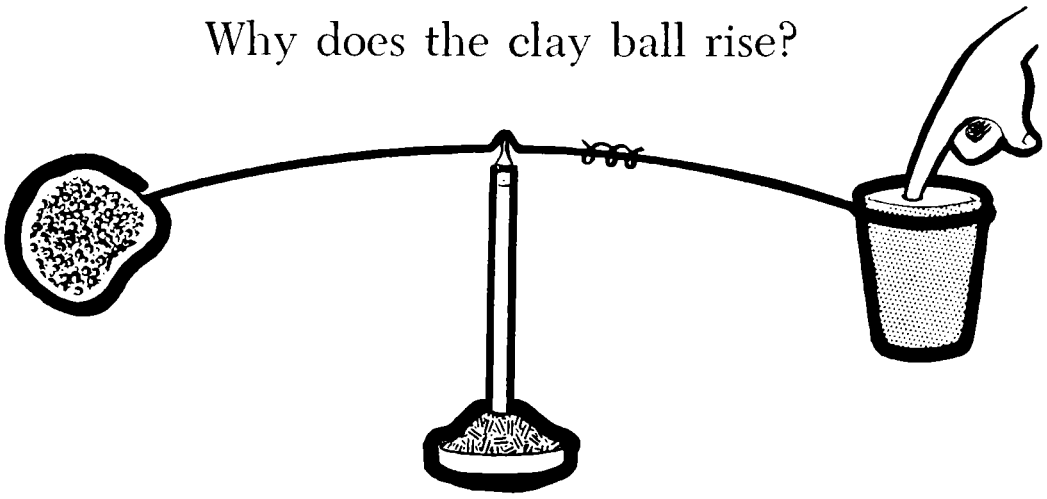
If I used tall bottles (or tubes) in place of the jars?

If I heated the water and ink in one container with an infrared lamp?

If ice water were gently funneled under the hot water before the ink was added?

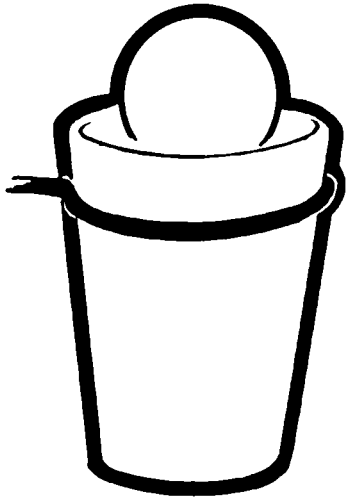
If I placed a drop of ink at various locations in the water with a long needle-nose medicine dropper?

Why does the clay ball rise?



If I poked into the water at different angles?
Use a shorter beam (and longer).
Straighten the beam.
If the beam were hanging on a string?

If I changed the size of the poker, poking first with a pencil point and second with the broad bottom end of another foam cup?



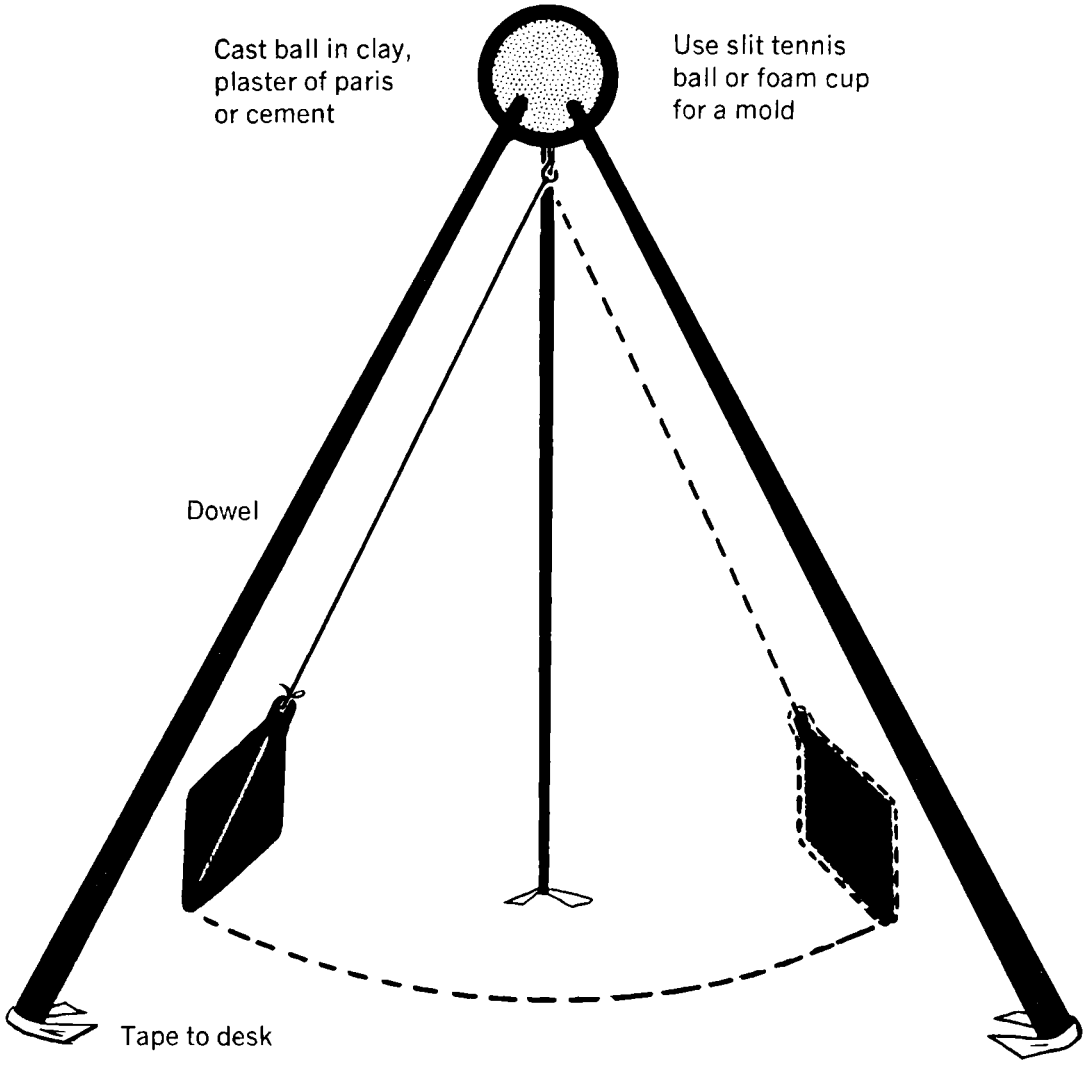
Blow gently on the water.

If the liquid were changed to salt water (milk, oil, or vinegar)?

If I hung the liquid from the beam instead of attaching the cup to the beam tightly?

If I floated a cork or a Ping-Pong ball on the water?

What controls the timing of the pendulum?



the weight or bob

If I substituted a foam ball (rock, bead, block, feather, nail and cork)?

If a leaky plastic tube of water (or sand) were used?

If I made the weight lighter (and heavier)?

Change the shape of a clay bob.

Make the bob smaller (and larger).

the arc (length of swing)

Barely swing the bob (1°).

Try big swings (180°).

the string

If I substituted wire (thread, cord, rope, stick, dowel, or board)?

Couple two pendulums together with a drinking straw.

Change the length of the string.

If the string were pulled shorter as the pendulum was swinging?

the fulcrum

If I used a tongue depressor taped to the edge of the table and put a slit in it for the string?

If a yardstick were taped to the top of a door or a bookcase?

If I oiled the fulcrum to eliminate some of the friction?

Use a hook for a fulcrum and let the pendulum swing freely on the point of the hook.

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